Reference Copy PIBS 3642e

FILE COPY

EVALUATION OF ALTERNATIVE TREATMENT STRATEGIES FOR CONTROL OF TRIHALOMETHANES IN UNFILTERED CHLORINATED WATER SUPPLIES

MAY 1998

Ontario

Ministry
of the
Environment

ISBN 0-7778-7456-3

EVALUATION OF ALTERNATIVE TREATMENT STRATEGIES
FOR CONTROL OF TRIHALOMETHANES
IN UNFILTERED CHLORINATED WATER SUPPLIES

MAY 1998

Cette publication technique
n'est disponible qu'en anglais.

Copyright: Queen's Printer for Ontario, 1998
This publication may be reproduced for non-commercial purposes
with appropriate attribution.

PIBS 3642E

XCG

ENVIRONMENTAL
ENGINEERING
SPECIALISTS

XCG File #3-608-01

EVALUATION OF ALTERNATIVE TREATMENT STRATEGIES FOR CONTROL OF TRIHALOMETHANES IN UNFILTERED CHLORINATED WATER SUPPLIES

FEBRUARY 24, 1998

Prepared for

ONTARIO MINISTRY OF THE ENVIRONMENT
WATER AND WASTEWATER OPTIMIZATION SECTION
STANDARDS DEVELOPMENT BRANCH
125 RESOURCES ROAD
ETOBICOKE, ONTARIO
M9P 3V6

Prepared by

XCG CONSULTANTS LTD.
1 PORT STREET EAST, SUITE 201
MISSISSAUGA, ONTARIO
L5G 4N1

XCG Consultants Ltd.
1 Port St. E., Suite 201
Mississauga, ON
Canada
L5G 4N1
Tel: (905) 891-2400
Fax: (905) 891-2554
E-mail:
xcg@inforamp.net

TABLE OF CONTENTS

Page No.

1. INTRODUCTION 1-1

2. SUPPLY SYSTEM REVIEW 2-1

2.1 Data Collection 2-1
2.1.1 Survey and Other Sources 2-1
2.1.2 Groundwater Source Review 2-2
2.2 Review of the Collected Data 2-2
2.2.1 Alternative Water Sources 2-4
2.2.1.1 Surface Water Source 2-4
2.2.1.2 Groundwater Sources 2-4
2.3 Water Quality Criteria 2-5

3. THM CONTROL TREATMENT STRATEGIES 3-1

3.1 Conventional Treatment 3-1
3.2 Alternative THM Control Treatment Strategies 3-2
3.2.1 Removal of Trihalomethanes 3-2
3.2.1.1 Air Stripping 3-2
3.2.1.2 Granular Activated Carbon Adsorption 3-3
3.2.2 THMs Reducing Disinfection Strategies 3-4
3.2.2.1 Ozone 3-4
3.2.2.2 Free Chlorine Disinfection Plus Ammonia 3-5
3.2.2.3 Chlorine Dioxide 3-5
3.2.2.4 Membrane Technology - Microfiltration 3-5
3.2.2.5 Iodine 3-6
3.2.3 Removal of THMs Precursors 3-6
3.2.3.1 Oxidants 3-7
3.2.3.2 Membrane Filtration 3-7
3.2.3.3 Biological Treatment Technologies 3-8
3.2.4 Treatment Strategy Selection 3-9
3.2.4.1 Selection Criteria 3-10
3.3 Other Strategies (Edmonds, 1996)(EPA, 1986) 3-14

4. COMMUNITY SUPPLY REVIEW 4-1

4.1 Seasonal Treatment 4-1
4.2 Partial Flow Treatment 4-1
4.3 Supply System Treatment Alternatives 4-2
4.4 Red Lake and Wendover Proposed Treatment Facilities 4-4
4.5 Process Summary Comparisons 4-5

5. ALTERNATIVE TREATMENT STRATEGY COSTS 5-1

6. REFERENCES 6-1

TABLES

Table 2.1 Summary of Raw Water Quality and THM Concentration 2-3
Table 4.1 Comparison of Chlorine/Chloramination Only and Conventional Chlorination Only Drinking Water Treatment Processes 4-5
Table 4.2 Comparison of Chlorine Dioxide Disinfection Only and Conventional Chlorination Only Drinking Water Treatment Processes 4-6
Table 4.3 Comparison of Microfiltration and Conventional Drinking Water Treatment Processes 4-7
Table 4.4 Comparison of Nanofiltration and Conventional Drinking Water Treatment Processes 4-8
Table 4.5 Comparison of Slow Sand Filtration and Conventional Drinking Water Treatment Processes 4-9
Table 5.1 Cost Estimate for Estimate for Upgrade of Water Treatment Facilities: THM Study Population Based Flow 5-2
Table 5.2 Cost Estimate for Estimate for Upgrade of Water Treatment Facilities: THM Study Based on Questionnaire Flow 5-5

FIGURES

Figure 3.1 Colour Based Treatment Strategy Decision Tree

APPENDICES

Appendix A System Data
Appendix B Groundwater Preliminary Assessment
Appendix C Red Lake and Wendover Proposed Treatment Facilities
Appendix D Cost Estimates

1. INTRODUCTION

Discovery of disinfection by-products, including chloroform - a trihalomethane (THM), in drinking water in 1974 triggered concern in the drinking water industry. As a result, the scientific drinking water community has conducted extensive research into identifying these compounds and their potential health effects, as well as developing means of reducing their formation or concentration in our potable water systems.

These studies led to the establishment of maximum allowable concentration limits in potable water systems. The Ontario Drinking Water Objective (ODWO) of 350 μg/L total trihalomethanes (THMs) was established in 1978. In June 1996, the Ontario Ministry of the Environment and Energy (MOEE) made the decision to adopt the proposed interim maximum acceptable concentration (IMAC) objective of 100 μg/L THMs in drinking water, determined as a running annual average of quarterly samples.[1] (MOEE, 1995) This new limit can often be achieved through optimization of conventional water treatment processes.

In Ontario there are at present approximately 40 communities with municipal surface water supply systems with no treatment other than disinfection by chlorination. Eleven[2] of these surface water supplies were selected for study because the concentrations of THMs in the treated water were found to be over 100 μg/L on several occasions. The purpose of this study is to identify treatment alternatives, other than conventional treatment (defined as treatment with coagulant addition) for the reduction of THMs at these communities. It should be noted that raw water quality is variable and in particular it varies with the annual seasons. Therefore any proposed alternative supply strategy must be capable of operation through a seasonal range of raw water qualities.

The twelve water supplies identified for review in this study are: Balmertown; Cochenour; Hudson; Madsen; McFarlane Lake; Port Carling; Red Lake; Sioux Lookout; Thunder Bay - Loch Lomond; Vermilion Bay; Wendover; and Thunder Bay - Bare Point.

---

[1] 'This IMAC is based on the risk associated with chloroform, the THM most often present and generally found in the greatest concentration in drinking water. The guideline is designated as interim until such time as the risks from other disinfection by-products are ascertained.
It is not expected that all water systems will be able to meet this revised THMs guideline immediately. When the systems are expanded or upgraded, every effort should be made not only to meet the revised guideline, but also to reduce concentrations of THMs to as low a level as possible. The preferred method of controlling disinfection by-products is precursor removal; however, any method of control employed MUST NOT compromise the effectiveness of water disinfection'

[2] Because the Thunder Bay municipal drinking water supply is made up from two distinct surface water supplies, Bare Point and Loch Lomond, the Bare Point WTP, which does not produce high levels of THMs, was included in this study to provide alternative options to treating raw water from Loch Lomond.

The key objective of this preliminary study is to identify feasible alternatives to conventional water treatment which provide microbiologically and chemically safe water, while having regard for aesthetic water quality and costs.

The main components of this study consisted of:

1. Collection of site-specific data on the existing facilities, equipment and capacities, raw and treated water quality, chemicals utilized, and dosages;
2. A search for a full range of technically established, modern drinking water treatment processes;
3. Investigation of the geographical locality of each community for alternative raw water sources with better treatability potential, or alternative treated water supplies of better finished water quality;
4. Identification of up to three alternate water treatment strategies for each community taking into account potential problems with operation in remote locations with few community technical resources ; and,
5. Estimation of the costs for each recommended alternative, as compared to costs for a conventional treatment scheme at each community.

Section 2 consists of an objective review of the collected data and the methods used to collect and collate it. It includes a brief discussion of the information and sources used.

Section 3 consists of a critical review of established alternative water treatment processes based on current, publicly available literature. It includes the criteria used in selecting the feasible alternative treatment strategies and a decision matrix created for use in this study to select the site specific treatment alternatives.

Section 4 consists of an assessment of each community supply on the basis of the decision matrix developed in Section 3, with the feasible treatment alternatives presented in a tabular form.

Section 5 provides a brief discussion of the approach taken in determining the capital and annual operation and maintenance (O&M) costs associated with each alternative. These costs are summarized and compared to the costs associated with a typical conventional treatment facility.

2. SUPPLY SYSTEM REVIEW

A review of each community drinking water supply system was conducted. This review included collection of data on raw and treated water quality, chemical dosages, and existing facility equipment and capacities. Follow-up confirmation or clarification was sought in many instances. However, the reader should note that on-site verification was not part of this study. On-site verification is strongly recommended before further specific action is taken.

2.1 Data Collection

2.1.1 Survey and Other Sources

Data was collected for each community supply by way of a survey. A form, herein referred to as the MOEE THM Survey Form, was developed to help obtain the operating and water quality data from each community. There were four parts on the survey form: Background Information, Facility Description, Alternative Supplies, and Other Information. The supply system staff were asked to fill out the form to the best of their knowledge and return it as soon as possible. One to two years of data were requested, including demand figures; raw and treated water quality; chlorine dosages; and residuals at the chlorine injection location in the distribution system. Copies of the MOEE THM Survey form are on file with the Ministry of the Environment.

Communication with each supply system staff contact, as supplied by the MOEE, was initiated by telephone in August of 1996. The MOEE THM Survey form was subsequently distributed, by fax, to each of the supply system staff contacts identified from the initial communication. Included with each form was a letter from the MOEE Science & Technology Branch requesting the assistance of each community to provide the necessary data as requested. Where responses were not received within a reasonable period of time, the data was obtained via telephone or collected from alternative sources. Some uncertainty in the accuracy of the data was identified, but was not considered to significantly affect the accuracy of the analysis undertaken in this study. Where necessary, alternative sources of water quality data were identified and obtained through the MOEE. This included information from facilities participating in the MOEE Drinking Water Surveillance Program.

The sources of information used for each supply system are identified in Table A.1, Appendix A. A summary of the supplied data, as well as copies of the actual data and tables have also been included in Appendix A. The relevant data was compiled (Table 2.1) to provide a basis for analysis of treatment needs for each water supply.

The author cautions that more details will be needed for full design work. For example, details regarding the condition and capacity of existing equipment may have an impact on the facility design and costs. Site visits will be an essential component of any design work.

2.1.2 Groundwater Source Review

A preliminary assessment of the potential for significant groundwater supplies was performed for each location. The assessment involved review and interpretation of available geological and topographic maps for the geographical region of each community. Details of the above review are provided in Appendix B. Results of this review are presented and discussed in Section 2.2.1.

2.2 Review of the Collected Data

The quality of each system raw water supply was reviewed. The raw water turbidity as Formazin Turbidity Units (FTU)[3], colour, and dissolved organic carbon (DOC) concentrations were extracted from the collected data and are shown below in Table 2.1. Also included in Table 2.1 are the reported THMs concentrations and the percent reduction required to achieve the 100 μg/L THMs goal.[4]

Interpretation of the historical water quality data was carried out without field verification. For example, the raw water colour reported was assumed to be the "true" colour as opposed to the "apparent" colour which often includes some influence from turbidity.

Technologies necessary to reduce colour to the aesthetic ODWO of 5 Colour Units (CU) tend to be associated with higher capital and O&M costs, for example the higher cost of nanofiltration (which can removes colour) versus micro or ultrafiltration (which do not remove colour but have other specific benefits in water treatment - refer to Section 3.3.2 for more details)

In selecting alternative treatment strategies, the community acceptance and regulated requirements for colour reduction can very significantly impact the choices available and costs of treatments. (For a discussion of raw water quality criteria refer to Section 2.3).

---

[3] Formazin Turbidity Units (FTU) are equivalent to Nephelometric Turbidity Units (NTU).

[4] In general, the dominant trihalomethane formed from these water sources was chloroform - greater than 93% of the reported total THMs.

Table 2.1 *Summary of Raw Water Quality and THM Concentration*

SUPPLY SYSTEM	RAW WATER					EXISTING CHLORINATED WATER		
	COLOUR		TURBIDITY		D.O.C.	TRIHALOMETHANES		
	Avg. (CU)	Max. (CU)	Avg. (FTU)	Max. (FTU)	Avg. (mg/L)	Avg. (ug/L)	Max. (ug/L)	Reduction Required (based on max. THMs)
Balmertown	37	42	1.1	1.7	10	140	260	62%
Cochenour	42	59	0.88	1	11	220	330	70%
Hudson	22	31	3.0	4.3	7.2	140	210	52%
Madsen	24	28	0.68	1	10	180	320	69%
McFarlane Lake	13	17	0.99	1.4	4.2	140	230	57%
Port Carling	9.3	17	0.52	0.66	3.2	93	260	62%
Red Lake	32	37	0.6	0.8	9.6	140	210	52%
Sioux Lookout	39	54	1.3	5.2	9.1	160	230	57%
Thunder Bay - Bare Point	2.7	3.6	0.63	0.98	1.6	34	45	--
Thunder Bay - Loch Lomond	13	14	0.63	0.85	4.9	110	130	23%
Vermilion Bay	8.8	9.7	0.63	0.83	4.9	62	130	23%
Wendover	46	53	3.4	5.3	5.4	200	220	55%

*all values rounded to two significant figures

CU - colour units

FTU - FormazinTurbidity Units

Table 2.1 Summary of Raw Water Quality and THM Concentration

SUPPLY SYSTEM	RAW WATER					EXISTING CHLORINATED WATER		
	COLOUR		TURBIDITY		D.O.C.	TRIHALOMETHANES		
	Avg. (CU)	Max. (CU)	Avg. (FTU)	Max. (FTU)	Avg. (mg/L)	Avg. (ug/L)	Max. (ug/L)	Reduction Required (based on max. THMs)
Balmertown	37	42	1.1	1.7	10	140	260	62%
Cochenour	42	59	0.88	1	11	220	330	70%
Hudson	22	31	3.0	4.3	7.2	140	210	52%
Madsen	24	28	0.68	1	10	180	320	69%
McFarlane Lake	13	17	0.99	1.4	4.2	140	230	57%
Port Carling	9.3	17	0.52	0.66	3.2	93	260	62%
Red Lake	32	37	0.6	0.8	9.6	140	210	52%
Sioux Lookout	39	54	1.3	5.2	9.1	160	230	57%
Thunder Bay - Bare Point	2.7	3.6	0.63	0.98	1.6	34	45	--
Thunder Bay - Loch Lomond	13	14	0.63	0.85	4.9	110	130	23%
Vermilion Bay	8.8	9.7	0.63	0.83	4.9	62	130	23%
Wendover	46	53	3.4	5.3	5.4	200	220	55%

*all values rounded to two significant figures

CU - colour units

FTU - FormazinTurbidity Units

Patania *et al.*, 1995). Efficient reduction in the number of these pathogens can be achieved in turbidity removal processes. In particular, microfiltration can provide up to 6 log removal (one million times removal) (Memtec, 1996) of cysts which are difficult to inactivate with chemical disinfection alone (for example *Cryptosporidium*).

The cost impact of full conventional treatment implementation at the sites of interest to achieve turbidity levels sufficient for pathogenic cyst removal (turbidity maintained below 0.1 NTU) may be significant, but may be necessary in the long-term. However, in this review, the final water turbidity objective of 1 NTU was used since the likelihood of significant source contamination with pathogenic cysts, such as *Cryptosporidium,* was considered to be low in the communities studied. This should be verified and taken into consideration before adopting any treatment strategy recommended by this report.

A moderate potential for municipal groundwater supplies exists for four communities. It is recommended that a more detailed review be conducted for these locations (refer to Appendix B for steps involved in a detailed review), including measurement of the raw water quality, the potential for THM formation, and the water colour. In Section 2.3, more detail on how each community might make the decision on the degree of colour which would be acceptable.

2.3 Water Quality Criteria

The primary concern is that health be protected. This means microbiologically and chemically safe water is required as first priority. Meeting the health related drinking water quality criteria set out by the ODWO was considered the fundamental requirement of any alternative treatment strategy. The aesthetic criteria, such as temperature and odour, were considered desirable and therefore have a lower priority and their achievement can be an economically influenced decision.

Discussions with the MOEE regarding the significance of colour as an aesthetic drinking water objective, resulted in the consideration of treatment alternatives which do not fully remove colour. Relaxation of the aesthetic maximum desirable colour objective of 5 CU could be considered if the water produced is microbiologically and chemically safe. Treatment processes which focus on disinfection and the lowering of THMs in the treated water to below 100 μg/L were therefore considered for application to supplies with raw water colour levels up to 15 CU[5].

Further, treatment strategies whose primary goal was microbiological and chemical safety without specific regard to the finished water colour, are also considered as options. This is because a community might wish to adopt this relaxed colour limit, if acceptable for their community, when economic factors to achieve this aesthetic objective are significant. The decision may be influenced by the community's perception of water quality (though treated water colour in these communities may not have previously been an issue) or the financial burden which the community is willing to accept for removal of colour. The community may alternatively choose to remove the colour from the water for consumption by point of use devices.

Due to the increased concern over *Cryptosporidium* and *Giardia* cysts many municipal water systems in Ontario which use conventional treatment have set their treated water turbidity goal to be 0.1 NTU or less at all times. Recent evidence has suggested that maintaining treated water turbidity to less than 0.1 NTU significantly reduces the risk of microbial pathogen entry into drinking water systems (Logsdon *et al.*, 1988;

---

[5] The U.S. EPA maximum contaminant level (MCL) for colour is 15 colour units. The MCL for colour is part of the U.S. EPA national secondary drinking water regulations which concern contaminants that may adversely affect the aesthetic quality of drinking water. The national secondary drinking water regulations are intended as guidelines and are therefore not federally enforceable. (Montgomery, 1985)

precursor removals by coagulation/sedimentation plants have been experienced in the range from 16 to 41 percent, and reduction by direct filtration plants range from 13 to 100 percent (Symons, 1981).

Other reduction techniques include altering the point of chlorine addition and applying an alternate disinfection method.

For small[10] communities conventional treatment systems may not be appropriate because they are operator intensive (require constant skilled supervision), require the use of several chemicals, require on-site storage of spare parts, and need a high degree of instrumentation for control.

3.2 Alternative THM Control Treatment Strategies

3.2.1 Removal of Trihalomethanes

Treatment strategies proposed for removal of THMs include oxidation, air stripping (aeration), and adsorption. Oxidation of THMs has generally been unsuccessful (Symons et al, 1981) and is therefore not considered further as a treatment strategy. Air stripping and adsorption processes have demonstrated, with varying degrees of success, removal of THMs after their formation, and are discussed further in Section 3.2.1.1.

The most significant advantage of these treatment strategies is that the utility may not have to change from the present disinfection practices (free chlorination).

The disadvantages with these approaches include:

a) lack of precursor removal - after removal of the THMs from the water, the remaining precursors continue to react with any free chlorine to produce THMs; and

b) transfer of contaminant to a second medium - the THMs are transferred from the water to the second medium (e.g. air or activated carbon). This second medium, now contaminated, has to be dealt with accordingly, either through treatment or appropriate disposal.

3.2.1.1 Air Stripping

Trihalomethanes can be removed from treated water with the use of aeration processes (e.g. allowing the water to stand for a period of time before use, diffused air aeration, tower aeration, or packed column aeration). Aeration processes are more effective in the removal of THMs containing chlorine than THMs containing bromine (Symons et.

---

[10] It is recognized that the treatment plant requirements at Thunder Bay, at approximately 27 ML/Day, do not fall into the "small" category and that this community can afford the capital and operating costs associated with more sophisticated technology

3. THM CONTROL TREATMENT STRATEGIES

Trihalomethanes[6] can be formed through the reaction of free chlorine with naturally occurring organic compounds (THMs precursors[7]).

A. Under typical circumstances, the THMs produced in drinking water are dominated by chloroform, bromodichloromethane, dibromochloromethane, and bromoform, with chloroform usually occurring in the highest concentration [(Symons et al, 1981) McGuire, 1994) (White, 1986)]. This was found to be the case for the supply systems investigated in this study.

B. The rate of formation of THMs is fairly slow, taking hours/days to complete-depending on the reaction conditions (i.e., temperature, characteristics and concentration of THM precursors and chlorine, competing reactions, and pH). (Symons et al, 1981)

The three basic treatment approaches available to reduce the concentration of THMs in drinking water systems are:

1. removal of THMs after they are formed;
2. removal of THM precursors before chlorine is added; and
3. use of an alternative disinfection method that produces less THMs.

A brief discussion of available and established treatment strategies is presented in the following sections. Only treatment strategies not requiring the addition of a coagulant, such as alum, polyaluminum chloride, or ferric chloride, were considered. The referenced literature can be referred to for further information.

3.1 Conventional Treatment

Conventional treatment processes are well established and can remove much of the natural precursors with sludge formation/removal. Either full conventional treatment[8] or conventional direct filtration[9] was used as the basis for comparison.

The ability of conventional treatment to reduce the THM formation potential is generally attributed to the removal of THM precursors from the water. THM

---

[6] Trihalomethanes are compounds in which three halogen atoms (any of chlorine, bromine, iodine, fluorine) have replaced three hydrogen atoms in the methane molecule. The four most common THMs found in drinking water are chloroform, bromodichloromethane, dibromochloromethane, and bromoform; with chloroform usually occurring in the highest concentration. (McGuire, 1994) (White, 1986)

[7] THM precursors are: natural organic compounds found in all surface water and groundwater; a result of the decomposition of vegetation; often found to consist of humic and fulvic acids.

[8] Full conventional treatment includes coagulation, sedimentation, and filtration, plus disinfection.

[9] Conventional direct filtration includes coagulation and filtration, plus disinfection, but not sedimentation.

3.2.2 THMs Reducing Disinfection Strategies

The reaction between free chlorine and naturally occurring organic compounds in raw water sources is responsible for the formation of THMs. This would indicate that minimizing free chlorine usage or contact time would reduce the amount of THMs produced. This would include:

- the use of a disinfection chemical which does not produce THMs (e.g. ozone and chlorine dioxide),
- the use of UV light, the combination of the residual free chlorine after disinfection with ammonia to limit the production of THMs, and
- the use of mechanical processes such as microfiltration to remove bacteria, which will reduce the need for extended contact with chlorine.

The most common alternative disinfection chemicals used are: ozone, chlorine dioxide, and chloramine. Ultraviolet radiation has recently gained popularity as part of raw water disinfection strategies. The potential use of iodine, as an alternative disinfectant, was also reviewed.

At the technology forefront are membrane processes which are becoming increasingly considered for reducing microbiological risks and chemical disinfectant needs. Other mechanical processes, which remove particles, can aid the disinfection process, but are not considered in this section as barriers to microbiological hazards. Conventional treatment processes which utilize coagulant aids to remove particles also fall under this category, but are excluded from the following discussions because they are specifically considered alternatives in this report, as discussed earlier, but rather the basis upon which these alternatives are compared.

The author advises that use of an alternative disinfection strategy, that does not include filtration, must be based on detailed knowledge of the source, its protection, and specific local issues including informed agreement of the community.

3.2.2.1 Ozone

Generally, ozone is well accepted as an oxidant for taste and odour control, colour removal, and iron and manganese removal. However, it is often only successfully used in combination with coagulation-sedimentation and a biological filtration and/or bioadsorption step to remove the biodegradable organic materials which may be produced.

Although ozone is a strong disinfectant, it does not persist (maintain a residual) and therefore requires a second disinfectant to provide continued protection in the distribution system.

al., 1981). In addition to the advantages and disadvantages mentioned above, several additional problems are associated with aeration processes:

a) potential reintroduction of bacteria into the treated water - pre-treatment of the air may be necessary to remove airborne bacteria before intimate contact with the water;

b) potential air pollution problem - THMs introduced into the environment. This may be controlled through treatment of the contaminated air to remove or destroy the THMs before being discharged (e.g. treatment of the contaminated air with carbon adsorption (EPA, 1990);

c) it is energy intensive to achieve the high air to water ratios necessary; and

d) there is the potential for freezing during below zero weather.

Though removal of THMs by aeration is feasible, the associated disadvantages increase cost and complexity, thus making it an unattractive alternative for the communities being assessed.

3.2.1.2 Granular Activated Carbon Adsorption

Granular activated carbon (GAC) adsorption involves the transfer of THMs from the water to the surface of the carbon. GAC adsorption is more effective in the removal of THMs containing bromine (Symons et. al., 1981); this is not the situation for the 12 locations reviewed in this study. The advantage of carbon adsorption is that the process is reversible; the carbon media can be regeneration and reused (EPA, 1990), though the heat treatment process used for regeneration is expensive.

The disadvantages of GAC adsorption for THMs removal includes:

a) desorption - If the concentration of the contaminant in the water drops, the contaminant may then transfer off the carbon and back into the water. (EPA. 1990)

b) short bed lives - Complete removal of the THMs is only achieved by a fresh activated carbon bed and bed lives in the order of only 8 weeks are experienced (Symons et al, 1981). Short bed lives significantly impact O&M costs because of the need for frequent waste disposal or regeneration of carbon.[11]

Because of the potential disadvantages associated with GAC adsorption and the preferential removal of other contaminants over chloroform (the dominant THM), this process is not attractive by comparison to other available treatment methods, and is not considered further.

---

[11] "The carbon and reactivation system, including either onsite or off-site carbon reactivation, compose nearly half of the GAC system costs." (EPA, 1990)

most fecal coliforms), and some viruses. MF, when used in combination with a chemical disinfectant (only a short contact time is necessary), can be rendered water microbiologically safe. (Memtec, 1996)

Membrane effectiveness must be monitored by membrane integrity diagnostic technology (e.g. static pressure loss or particle counting). The appropriate monitoring device and/or fail-safe system must be carefully chosen, with consideration of maintenance factors, for small or remote water supply systems.

Readers are reminded that use of MF removes the more difficult to disinfect microorganisms, such as *Giardia* cysts, from the water. This then requires shorter chlorine contact times or less chlorine to achieve adequate disinfection, with consequently reduced THMs

3.2.2.5 Iodine

The use of iodine in water supplies has historically been limited to emergency water treatment by the military, for seasonal disinfection of water at trailer parks and campgrounds, and in individual home well water systems. Despite its strong disinfectant qualities, its high cost and presently agreed low, but unqualified, potential physiological effects has limited its general acceptance[14].

Other considerations which would be crucial to the use of iodine as a disinfectant would be the potential of undesirable disinfection by-products (including THMs) and their health effects. However, iodine only slowly forms by-products and these are generally suspected to have low toxicity (Edmonds, 1997).

Because iodination is not a widely used or established municipal disinfection method, it was not considered further.

3.2.3 Removal of THMs Precursors

Without the use of conventional treatment processes (coagulation-flocculation-sedimentation-filtration), precursors can be removed by membrane, biological filtration, or chemical oxidation. The extent of removal varies with the treatment process, the raw water composition, and the mode of operation. The processes outlined below for THMs precursors removal include: ozone and chlorine dioxide oxidation; biological slow sand and high rate filtration; and membrane filtration.

---

[14] Few studies have been conducted to determine the effects of the prolonged use of iodine on human health. Studies that have been conducted have not found evidence of any adverse effects on the general health or thyroid function at doses up to 1.0 ppm. (White, 1986)

Also, incomplete oxidation of organic compounds by ozone often results in an increased concentration of biodegradable material in the finished water, which can produce extra THMs and an increase in the potential for downstream biological growth; therefore requiring a treatment step to remove the biological material prior to chlorination and distribution. Complete oxidation requires high dosages which are not economical.

Ozone technology is relatively expensive and complex to operate. A high degree of skill and attention is required. The use of ozone was not considered further because of the capital requirements and the system complexity - ozone was not considered appropriate for the relatively small water systems reviewed in this report.

3.2.2.2 Free Chlorine Disinfection Plus Ammonia

Addition of ammonia after disinfection with free chlorine is a potentially feasible strategy to limit the formation of THMs. This is because free chlorine will more easily combine with ammonia than the THM precursors and form chloramines[12]. Chloramine persists longer than free chlorine because it has a lower chemical reactivity. By elimination of the free chlorine, the formation of THMs will be stopped. Monochloramine has been successfully used for many years in water treatment (McGuire, 1994).

3.2.2.3 Chlorine Dioxide

Chlorine dioxide is a strong disinfectant that does not form THMs. It is a more potent bactericide and viricide than chlorine, and maintains a residual that controls the potential of biological regrowth in distribution systems. The main disadvantage of chlorine dioxide use is the potential for formation of the disinfection by-products, chlorite and chlorate ions[13], in finished drinking water.

The degree of risk associated with using chlorine dioxide in drinking water is questioned in the literature, though it is still recommended to minimize the chlorite ion residual in drinking water (White, 1986). Current toxicological studies are ongoing which may reduce the concern regarding chlorine dioxide by-products.

3.2.2.4 Membrane Technology - Microfiltration

Microfiltration (MF) systems are becoming more economical and less operator intensive. They are effective in removing all particles greater than 0.2 micrometers in size. This includes the removal of protozoan cysts (*Giardia Lamblia* and *Cryptosporidium*), bacteria (a large portion of which are greater than 0.2 μm including

---

[12] Municipal water supplies applying ammonia as a post disinfection step would need to inform the community of its use because of its adverse effects on kidney dialysis machines and home aquariums. -

[13] At present these substances are not regulated in Canada, but the U.S. EPA has proposed to limit the concentration of chlorite in finished water to below 1 mg/L due to the potential toxicological effects.

Particles trapped within the membrane pores can result in membrane fouling. Depending on the type of membrane being considered and the raw water quality, pretreatment to prevent membrane fouling or plugging/sealing[16] can be complex and expensive. To reduce the rate of fouling, a microfilter may be used to remove larger particles (turbidity) upstream of nanofiltration.

Membranes operated at fixed pressure experience reduced flux (product throughput) during periods of cold temperatures (or higher pressures are required to operate at the same rate of production[17]). Pilot plant studies of this technology are required to determine the suitable membrane area and fouling rates for a specific raw water source and also to determine the appropriate post disinfection strategy necessary to reduce the concentration of THMs in the treated water.

3.2.3.3 *Biological Treatment Technologies*

Biological treatment technologies including slow sand filtration and high rate biological filtration are considered in this section as alternative treatment processes for the reduction of THMs.

Slow Sand Filtration

Slow sand filtration[18] has been successfully applied in many small water systems with low quantity demand, low colour or algae content. This technology can be applied to water with high initial colour, provided that the finished water colour is acceptable to the community (as discussed in Section 2.3). This treatment strategy is simple to operate and maintain, and can achieve up to 15 to 20% removal of THMs precursors (First Nations). Consequently, final disinfection may be accomplished by a lower disinfectant dosage and/or shorter contact time. However, this combination is not extensively used and may be considered by some as a “new technology”, even though slow sand filtration has been used for many years in water treatment. Slow sand filtration is also an effective treatment for removal of bacteria and cysts. (EPA, 1990)

Application of an alternative disinfection strategy will further reduce the potential for THMs formation. This simple-to-maintain-and-operate process is predicted to be applicable at some of the locations being assessed in this report.

A disadvantage of this process is the relatively large area required by the filters. In colder climates, as in the cases being considered, these filters must be kept from freezing and light to achieve effective biological action.

---

[16] Membrane sealing can result from dissolved materials precipitating onto the membrane, such as carbonates and sulphates. (First Nations)

[17] Cold temperature effects result from the increase in viscosity of the water as the temperature drops.

[18] Slow sand filtration - the slow passage of water, by gravity, through a sand bed with a naturally produced biological layer on the surface. The majority of particulate matter is removed in the top several inches of sand.

3.2.3.1 Oxidants

Ozone

Ozone is a very strong oxidant and has been used in water treatment since the 1920s for taste and odour control, and colour removal. At doses commonly used, ozone is capable of reducing approximately 10-15% of the THM precursors (First Nations). Section 3.2.1 notes that it is preferable to combine ozone oxidation with coagulation-sedimentation and a biological filtration and/or bioadsorption step to remove any biodegradable organic materials produced. Because of the high capital, O&M costs and complexity of the technology associated with ozonation, it was not considered a feasible disinfection strategy for the supply systems under review.

Chlorine Dioxide

Chlorine dioxide, other than being a good disinfectant alternative, can reduce THM precursors by approximately 10 to 15% at dosages normally used for taste and odour control (First Nations). Because 15% was insufficient removal at the supply systems in this study, chlorine dioxide was not considered further as a THM precursor oxidant.

3.2.3.2 Membrane Filtration

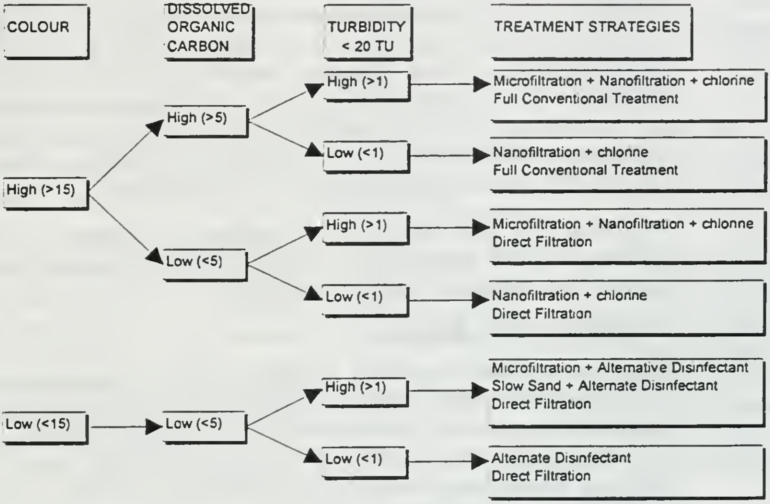
Membrane[15] filtration (ultrafiltration, nanofiltration, and reverse osmosis) can be very efficient in removing particles, TOC, DOC, THM precursors, other organic compounds and microorganisms and even ionic dissolved salts. Studies using reverse osmosis have demonstrated 67 to 99% removal of organic compounds but the technology is expensive compared to nanofiltration and ultrafiltration, and is therefore not considered further in this report. Nanofiltration, though still relatively expensive technology, has been shown to be suitable for THM precursor removal from highly coloured surface waters with moderate turbidity. THM reductions in the range of 38 to 89% have been achieved. Ultrafiltration is not considered to be adequate for THM precursor removal. (First Nations)

Membrane processes require extra energy to operate; water must be pumped through at elevated pressures. Reverse osmosis operates at the highest pressures (200 to 600 psi), followed by nanofiltration (70 to 200 psi), and ultrafiltration (25 to 120 psi). For comparison, MF operates at pressures ranging from 7 to 15 psi. These pressure ranges are related to the pore sizes of the membrane, with reverse osmosis having the smallest pores. (First Nations)

---

[15] Synthetic flexible material with micro-pores which prevent the passage of particles larger than a specified size and allow smaller particles to flow through.

Figure 3.1 Colour Based Treatment Strategy Decision Tree


COLOUR
DISSOLVED ORGANIC CARBON
TURBIDITY < 20 TU
TREATMENT STRATEGIES
High (>15)
High (>5)
High (>1)
Microfiltration + Nanofiltration + chlorine
Full Conventional Treatment
Low (<1)
Nanofiltration + chlorine
Full Conventional Treatment
Low (<5)
High (>1)
Microfiltration + Nanofiltration + chlorine
Direct Filtration
Low (<1)
Nanofiltration + chlorine
Direct Filtration
Low (<15)
Low (<5)
High (>1)
Microfiltration + Alternative Disinfectant
Slow Sand + Alternate Disinfectant
Direct Filtration
Low (<1)
Alternate Disinfectant
Direct Filtration

3.2.4.1 *Selection Criteria*

The selection criteria considered in developing the above decision tree include:

1. ability to meet ODWOs;
2. potential to reduce THMs;
3. overall cost by combination of capital and O&M costs;
4. reliability (established vs. experimental) and ease of adjustment to raw water quality changes;
5. ease/complexity of operation;
6. flexibility (with respect to expansion); and
7. process sensitivity to temperature.

Ability to Meet ODWOs/THM Reduction

Achieving microbiologically and chemically safe water was considered as paramount, and the aesthetic criteria were considered desirable, but not necessarily essential, and therefore were given a lower priority and allowed to be economically driven. For example, the aesthetic colour objective was set at 15 CU for process selection in this study (as discussed above in section 2.3).

High-Rate Biological Filtration

There are various high-rate biological filtration configurations available including pre-ozonation, addition of/or contact with activated carbon media, and second stage biological activated carbon filtration. These extra unit operations can contribute to the complexity of the system and to the cost. The simplest high-rate biological filtration process utilizing inert media (without the use of pre-ozonation) has achieved a 15 % reduction in THMs precursors. For comparison, the addition of GAC can increase the removal efficiency to approximately 40%. (First Nations)

In general, the high rate filtration configurations required to achieve significant removal of THMs precursors are relatively costly and complex to operate and were therefore not considered further in this report.

3.2.4 Treatment Strategy Selection

The three alternative treatment strategies for the 12 communities were based on several selection criteria. A first cut decision tree was developed for simplicity of selection (Figure 3.1). The analyses of the treatment strategies, provided in the preceding sections, were used as a basis for this decision tree. The decision tree selections are compared to conventional treatment in Section 5 of this report. The selection criteria are briefly explained to further define the procedures used to determine the potential alternative treatment strategies for each location.

The raw water criteria considered in this first cut include:

- relaxing the ODWO aesthetic colour objective to 15 CU (as discussed in Section 2.3),
- achieving a turbidity of at least 1 NTU, reducing the DOC to below 5 mg/L
- minimizing the THMs produced.

All of the treatment strategies recommended herein are applicable to small municipal water supply systems. Implementation of any of the recommended treatment strategies requires verification of land availability, assessment of the environmental impacts, and most importantly pilot-scale testing before a full-scale plant is constructed.

The most generally applicable of these combination processes is expected to consist of microfiltration (MF) with some colour removal process. Colour removal by chemical pretreatment is possible; however, probably only activated carbon colour removal processes would have the necessary simplicity and economy of operation.

Though the MF/carbon combination process operation is not currently practiced, the two separate technologies are commonly used in other combinations. MF is gaining particular attention as a barrier for pathogenic cyst diseases and carbon is widely used as a quality improvement add-on in drinking water treatment.

The use of carbon as a physical colour adsorbent or as a support for biological colour removal is relatively easy to operate successfully. However the process is limited to partial colour removal only at economic carbon usage rates. Activated carbon can be used as granulated activated carbon (GAC) in a bed or as a powdered activated carbon (PAC) and applied as a slurry. PAC has special advantages for application as needed and can be implemented with very little additional cost to a MF plant. A continuously operated bed is required for the biological colour removal process with the advantage that GAC can be backwashed and regenerated. Costs for this option are not provided because they are too variable for accurate estimation on a generic basis.

The MF/carbon combination process may also prove to be an attractive alternative to nanofiltration processes which may also be only partially effective in removing colour. The MF/carbon alternative may also prove more amenable to those communities where nanofiltration is suggested because of the need for high operating pressure and the potential for membrane fouling of the very small pores in the nanofiltration membranes. Additional pretreatment processes may be required.

Membrane filtration processes are very suitable for small water supply systems - although possibly somewhat more costly than conventional systems - because they can cope automatically and well with rapid raw water quality changes and can be designed for minimal or unattended operation. Also, these processes are modular, allowing for incremental expansion as water demand changes, rather than having to install projected full capacity to meet future demand predictions.

Lightly Coloured Raw Water

There are more options available for treatment of raw water sources with low colour and low DOC. The treatment alternatives include the use of alternative disinfectants and where the turbidity is greater than 1 NTU, some means of turbidity removal is suggested, such as slow sand or MF prior to addition of the alternate disinfectant.

The THMs reduction potential of each treatment strategy is highly dependent on the disinfectant used and the nature of the raw water. This may be crucial to the performance of the treatment strategies chosen. All of the selected treatment strategies, for this report, are postulated to be able to meet the microbiological and chemical safety requirements, but are only truly verifiable by bench tests which are relatively inexpensive - but were not part of this study.

Highly Coloured Raw Water

For the communities with highly coloured raw water sources in this study[19] (i.e. above 15 CU), the available treatment strategies were narrowed down to those involving nanofiltration or possibly to combinations of microfiltration with an additional colour removal process. Nanofiltration can remove colour and much of the THM precursors. Since much of the THM forming precursors and microorganisms are removed, it is possible to disinfect with less chlorine contact or with chloramination and so avoid exceeding the THMs limit. Continuation of chlorine disinfection with a shorter contact time is advantageous since the technology is well established and familiar to the operating staff at each of the communities.

In process selection and costing, it is important to recognize that the treatment of highly coloured water can be difficult whatever the process selected. Even with conventional processes colour may not be reduced sufficiently without significant coagulation chemical addition and consequent chemicals to "stabilize" the finished water. In these cases handling and disposal of the increased sludge becomes expensive.

Additional process steps and/or use of more complex and specially designed process combinations may even be needed. For example, an ideal treatment train might involve ozonation followed by biological treatment, in turn followed by conventional treatment. Such combinations are in use in European situations where low quality source water is all that is available. These complex combinations require much greater capital investment and operating skills than might be considered reasonable or achievable for many of the communities involved in this study.

In this context, if regular conventional treatment were not found to be easy to apply or be not very effective for colour removal, less complex process combinations which can offer complete safety assurance but which only produce partly decoloured water would merit serious consideration.

---

[19] The colour of these waters are generally attributed to dissolved organic materials.

Process Climate Sensitivity

Seasonal decreases in temperature can cause a decrease in the reactivity of oxidants, a decrease in the rate of biodegradation of biological processes, and increases in the viscosity of water. The increases in viscosity can affect membrane operating pressures by 20% or more, or the percent rejection.

3.3 Other Strategies (Edmonds, 1996)(EPA, 1986)

Supply of safe drinking water may also be achieved through the supply of bottled drinking water or individual point-of-use treatment systems. These options, which are in addition to and separate from treatment at the municipal scale, were excluded in this report from the formal analysis of alternatives assessed for each community. However, it may be of interest to each community to explore the suitability and costs associated with implementing and maintaining either of these programs in their particular community.

In the case of a bottled drinking water supply, the existing unfiltered, chlorinated municipal water supply would exist to meet household water needs other than that for human consumption.

Similarly, the installation of individual point-of-use treatment units in each household would treat only the water specifically intended for human consumption. This would involve only a portion of the presently supplied unfiltered, chlorinated water.

Other THM exposure routes, e.g. skin contact, should be explored if water supplied for other than consumption is very high in THMs.

Each person consumes approximately 2 to 5 litres of water per day. In comparison, each person uses approximately 300 to 400 litres of water per day. The options presented here might only provide the water actually consumed by each person, whereas a treatment strategy, design for the municipal supply as described in the previous sections, would treat the entire community demand, 300 to 400 litres per person per day.

Such a significant reduction in the quantity of water requiring full treatment could lead to the most economic strategy in both capital and O&M related costs. However, these options would require acceptance of some inconvenience and would require resolution of issues associated with program logistics, such as installation, maintenance responsibility, public education regarding other exposure routes[20], and monitoring program effectiveness.

---

[20] CAUTION: THMs may possibly be adsorbed through the skin.

Capital and O&M Costs

The capital and O&M costs were considered. More expensive process combinations, such as those involving ozone with GAC, were eliminated. For the locations with relatively high quality raw water (low colour, DOC and turbidity) more options were available. With high quality water, nanofiltration would have been technically equally suitable, but the higher cost of the technology, in comparison to using an alternate disinfectant, eliminated nanofiltration as a feasible alternative treatment process. Similarly, for communities with low water quality, nanofiltration is recommended, though reverse osmosis was equally technically feasible. Once again, the incremental cost between the two technologies eliminated reverse osmosis as a feasible alternative treatment process.

Reliability

Reliability and ease of process control were considered during the literature review. Processes that have not been established were not considered further because their reliability has not been proven in full scale practice. Reliability and ease of process control, with regards to handling raw water fluctuations, are specific to each technology. Fluctuations in raw water can be caused by rain events in rivers sources, spring runoff, and lake turnover. All the processes selected for each site are expected to be capable of handling the average raw water quality (as provided by the collected data), but it remains the task of the designer to consider the potential of seasonal and daily source fluctuation, demand fluctuations and other variances which may effect the process effectiveness.

Ease of Operation

The ease of operation is related to both the degree of skill required to understand the process operation and the degree of automation built into the system. For example, if the process strategy requires a high degree of skill to operate manually it may require a high degree of skill for maintenance and monitoring even when automated.

Flexibility

Flexibility to expand the system for future demands could not be determined from the information provided. Expansion, in many cases, may be limited by the availability of land, with the exception of membrane filtration units which are extremely compact. All the treatment strategies considered appear to be flexible to combine with other processes should the nature of the raw water change, for example a need for addition of pretreatment, odour control' or corrosion control. For example, addition of pretreatment to nanofiltration is feasible should the raw water turbidity experience a sustained increase.

considered to be an issue in the individual communities). This alternate scheme was not definitively pursued since adequate verification of groundwater availability has not been undertaken (Section 2.2.1 discusses groundwater potential).

In Section 5.0, the capital costs and O&M costs are discussed for these alternatives, as well as for the full conventional treatment option.

Further to the discussion in Section 2.3 regarding complete relaxation of the aesthetic colour objective (to community existing level), the following treatment strategies may all be considered, including:

- slow sand filtration plus alternative disinfection strategy;
- MF plus alternative disinfection strategy; or
- an alternative disinfection strategy without filtration[21].

The costs associated with the option of MF plus chlorine disinfection plus ammonia are included in Section 5.0 for the situation where complete relaxation of the colour objective is accepted and additional protection against pathogenic cysts is desired. The MF processes stand out on the basis of costs, simple operation, modular design, low area requirements, low maintenance, flexibility, and ability, of some proprietary systems, to automatically and continually monitor process integrity and effectiveness. In particular, this process would be suitable where either colour is low or colour varies seasonally (and is acceptable to the community or is combined with colour treatment at the point of use.)

4.3 Supply System Treatment Alternatives

The results of this colour based assessment are listed by groups of communities and further comment and alternatives are then considered.

Port Carling,
Thunder Bay/Loch Lomond,
Thunder Bay/Bare Point and
Vermilion Bay.

These communities each have stable, low-turbidity, low-colour raw water sources which could in-principle be free of resistant disease causing microorganisms and suitable to be treated by disinfection without filtration. Accordingly costs for disinfection only with chlorine/ammonia or with chlorine dioxide are provided.

Disinfection alone as a treatment has disadvantages even if THMs are controlled. First *Cryptosporidium*, a widely occurring intestinal parasite which causes disease, is

---

[21] This option may only be considered if studies can show that no *Giardia* cysts are present and the watershed can be protected from contamination.

4. COMMUNITY SUPPLY REVIEW

Selection of suitable candidate processes for each community were made on the basis of raw water quality (see Table 2.2). The Alternative Treatment Decision Tree presented in Figure 3.1 was then applied. The results are listed in Section 4.3.

4.1 Seasonal Treatment

Seasonal treatment (operation of treatment for part of each year) was also considered for each location. Only the raw water quality at Port Carling appeared to warrant consideration of seasonal treatment for THMs (based on 1995 water quality data). The turbidity remained below 1 NTU all year round, the colour was less than 15 CU, except for a spike in February (19 CU), and the DOC was less than 5 mg/L. The THMs exceeded the proposed 100 µg/L only during the summer months of June to September. Only processes which are not biologically based can be operated on an "as-needed" basis. For this reason, only the nanofiltration plus chlorination process selected for Port Carling was considered for seasonal operation, provided that chlorination is practiced all year round. This would mean that, during the months of high THM formation potential the water would be filtered then disinfected, and during all other months, the water would just be disinfected without filtration.

Because colour does not exceed 15 CU, on average, throughout the year, nanofiltration may not even be necessary if the community is willing to accept the relaxation of the colour objective with possible minor seasonal fluctuations above 15 CU. In this case, the community may decide to chlorinate during the winter months (as is presently.the case without exceeding the 100 µg/L limit of THMs) and add ammonia after disinfection with chlorine during the summer months (when increased THMs formation potential is experienced, i.e. a high concentration of THMs precursors is present in the source water).

4.2 Partial Flow Treatment

Treatment of part of the raw surface water flow with an alternative treatment was also considered, but this scheme was rejected because the operation of such a treatment scheme would be difficult to control. Determination of the percent split with seasonal and diurnal fluctuations in raw water quality would be a complex task and a high level of sophisticated monitoring equipment would be necessary to control the combined finished water quality. This design concept was therefore discarded on the basis that it would not likely provide sufficient control of microbiological and chemical safety.

Supplementing the surface supply with adequate quality groundwater during the summer months may result in a reduction of treatment needs, provided that the groundwater contains less THMs precursors and/or is less coloured (if this is testing a pretreatment step in combination with nanofiltration or the process of MF in combination with carbon to control colour.

McFarlane Lake

Application of the colour based selection procedure to this community supply indicates that slow sand filtration or microfiltration combined with chlorine and ammonia disinfection are suitable alternatives.

In all cases in selecting a process for any of the communities in this study will require raw water samples to be taken and first subjected to bench scale feasibility studies, then small scale batch tests. This testing may rapidly eliminate some process options. The remaining possibilities will then require testing as on-site continuous operation of small scale pilot equipment. The on-site pilot work is needed to provide operating experience, to confirm predicted treated water quality and to provide data for full scale plant design and accurate cost predictions.

In order for the reader to gain an appreciation of the major differences which may influence process choices, summary comparisons of the more common features of selected alternatives against regular conventional treatment are presented in the following tables.

4.4 Red Lake and Wendover Proposed Treatment Facilities

Two of the systems, Red Lake and Wendover, have already initiated plans to build conventional treatment processes. The Amended Certificate of Approval containing the details of the design for Red Lake and a letter from the design engineers for Wendover are included in Appendix C. The Red Lake treatment process will consist of a conventional treatment package unit with static mixing, flocculation, tube settler clarification and multi-media gravity filtration. Chemical addition will include liquid alum and a polymer for coagulation, and soda ash for pH control. Disinfection will be accomplished by chlorination. At Wendover, the proposed treatment system will also be based on the conventional processes of coagulation, sedimentation and filtration. Chemical addition will include alum and a polymer for coagulation, sodium hypochlorite for pH/alkalinity control and sodium hypochlorite for post disinfection.

Since conventional treatment is the base option considered feasible for reduction of THMs, no further comment will be made with respect to the proposed conventional systems at Red Lake or Wendover. Optimization of the processes may be necessary if the treated water THM concentrations at these two locations cannot be maintained below the 100 μg/L limit during operation.

highly resistant to chlorine and very resistant to chlorine dioxide may turn up episodically in the raw water and has the potential to cause disease outbreaks. Also particles may pass through treatment and can shield microorganisms which are then not killed or inactivated by the disinfectant. On consumption these particles may then cause disease.

In addition to this public health risk with disinfection alone, there could be aesthetic concerns. The occurrence of algae blooms, storm disturbed sediment and suspended plant debris, can create water quality issues and subsequent public concern.

Despite the fact that the four communities listed have a high quality raw water source it is probable that, processes which do not include a filtration stage would be unlikely to receive public health, MOEE or community approval. It is therefore recommended that the least costly filtration process be added to disinfection using chlorine dioxide or chlorine/ammonia for these supplies.

Balmertown,
Cochenour
Madsen
Red Lake
Sioux Lookout
Wendover

These six communities have lesser quality, more strongly coloured raw water than the four mentioned above. Application of the colour based selection process indicates only nanofiltration with chlorine is suitable for Cochenour, Madsen and Red Lake. Balmerton, Sioux Lookout and Wendover appear to have THMs- forming capability which is of concern and chloramination treatment to slow this formation will probably be needed in addition to the chlorine disinfection and nanofiltration.

Nanofiltration can be difficult to operate with some raw waters because of the potential for membrane plugging. These communities therefore may wish to consider testing a pretreatment in combination with nanofiltration or the process of MF. The community may also wish to try MF in combination with carbon to achieve colour reduction.

Hudson

Slow sand filtration with chlorine and ammonia disinfection or nanofiltration with chlorine and ammonia are candidate treatments. Approximate costing for these is provided.

Nanofiltration can be difficult to operate with some raw waters because of the potential for membrane plugging. The community of Hudson therefore may wish to consider

Table 4.2 Comparison of Chlorine Dioxide Disinfection Only and Conventional Chlorination Only Drinking Water Treatment Processes

Chlorine Dioxide	Conventional Chlorination
Advantages	
With suitable contact time and naturally particle free water excellent protection from bacteria and viruses is obtained	With suitable contact time and naturally particle free water, can provide good protection from bacteria and viruses
Can provide some *Cryptosporidium* damage and *Giardia* inactivation	Provides no protection against *Cryptosporidium* and limited protection from *Giardia*
Can produce a persistent level of disinfectant residual for distribution protection	Produces a moderately persistent residual
Produces insignificant amounts of disinfection by-products such as THMs	Produces THMs and haloacetic acid by-products
Requires modest contact times/tankage for effective protection	Requires longer contact times
	Tends not to produce unexpected by-products
May give substantial colour reduction	Generally less effective in colour treatment
Disadvantages	
Requires monitoring of chlorate and chlorite parameters as well as chlorine dioxide	Easily monitored
Requires use of highly reactive chemicals which need careful storage and handling	Requires careful storage/handling/use of reactive chemicals
Requires skilled operator attention and instrumental monitoring with alarms	Requires operator attention and instrumental monitoring with alarms
Offers only partial consumer protection	Offers consumer protection at a level often now considered to be inadequate
Requires separate storage and treatment buildings	Requires special combined treatment and storage building
Does not cope with algae, insects, fish leaves and other suspended debris.	Does not cope with algae, insects, fish leaves and other suspended debris.

Note:

Any process treating surface water which does not have a particle removing process stage can allow the passage of infectious organisms both in a free floating state or inside protecting suspended particles. The risk of disease from failure to inactivate/kill these organisms may be considered low in pristine conditions but this risk is extremely difficult to confidently confirm. It is recommended that disinfection only treatment processes be considered by communities as possibly acceptable only with very clean lake sources which have effective watershed protection programs in-place. In addition, in such cases, it is considered appropriate that seasonal water quality changes are used as triggers for community notification and application of temporary boil-water orders. .

4.5 Process Summary Comparisons

Table 4.1 Comparison of Chlorine/Chloramination Only and Conventional Chlorination Only Drinking Water Treatment Processes

Chlorine/Chloramination	Conventional Chlorination
Advantages	
With suitable contact time and naturally particle free water protection from bacteria and viruses is obtainable	With suitable contact time and naturally particle free water can provides good protection from bacteria and viruses
Produces a very persistent disinfectant residual for enhanced water quality protection in distribution	Produces a moderately persistent residual
Produces reduced amounts of the regular disinfection by-products such as THMs	Produces THMs
May produce new toxic by-products and biofouling unless controlled well	Tends not to produce unexpected by-products
Generally not effective in colour treatment	May produce some colour reduction
Disadvantages	
Presents only a partial barrier against water borne diseases found in surface water	Presents only a partial barrier against water borne diseases found in surface water
Provides no protection against *Cryptosporidium* and even more limited protection from *Giardia*	Provides no protection against *Cryptosporidium* and limited protection from *Giardia*
Requires considerable contact times especially in adverse temperature and pH conditions	Requires considerable contact times especially in adverse temperature and pH conditions
Requires use of an ammonia source which may need special storage and handling and additional chemical feed costs	
Can cause fishkill problems if spilled	Less environmentally hazardous
Requires additional distribution monitoring	
Can adversely affect kidney dialysis	
Does not cope well with algae, insects, fish, leaves etc.	Does not cope well with algae, insects, fish, leaves etc.

Note:

Any process treating surface water which does not have a particle removing process stage can allow the passage of infectious organisms both in a free floating state or inside protecting suspended particles. The risk of disease from failure to inactivate/kill these organisms may be considered low in pristine conditions but this risk is extremely difficult to confidently predict. It is recommended that disinfection only treatment processes be considered by communities as possibly acceptable only with very clean lake sources which have effective watershed protection programs in-place. In addition, in such cases, it is considered appropriate that seasonal water quality changes are used as triggers for community notification and application of temporary boil-water orders.

Table 4.4 Comparison of Nanofiltration and Conventional Drinking Water Treatment Processes

Nanofiltration	Conventional
Advantages	
Provides complete, fail-safe and usually automatic bacteria, virus and parasitic disease protection (with appropriate integrity monitoring technology)	Provides good protection if properly attended and skillfully operated
Can be operated with limited attention by skilled personnel	Requires skilled operator attention for at least several hours per day
May require pretreatment chemicals and also chemicals for membrane cleaning	Requires careful storage/handling/use of reactive chemicals and maintenance inventory and on-site maintenance skill
Produces, for the most part, an easily disposed-of chemically innocuous waste stream	Produces waste stream requiring treatment before discharge in addition to solids disposal
Produces lesser amounts of disinfection by-products e.g. THMs and can partly soften hard waters	Requires use of chlorine and/or other powerful disinfectant and longer contact/storage times producing more by-products
Requires small area building with a simple concrete pad and more modest tankage but larger than for microfiltration	Requires larger more complex building and large tanks
Relatively easily expanded to meet non-forecast demand	Must be built to appropriate size for full projected plant life
Often requires multi-season pilot	Often requires multi-season pilot and longer construction lead time
Copes automatically with some raw water quality changes	Difficult to operate well or automate for with rapidly changing raw water quality
Disadvantages	
Requires moderate/good quality non-fouling raw water which does not need large chemical adjustment	Capable of treating poor quality raw water
Often requires some chemical pretreatment or sand + cartridge prefiltration	
Can be reasonably effective in reducing colour without extra expense/processing	Can reduce water colour
Requires expensive filter replacement at ¯3 year basis - may even require upstream microfiltration for reasonable membrane life	Requires continued chemical supply
Requires considerably (20-50%) increased pumping costs	
May not cope well with algae or zebra mussel problems	
Capital cost may be a little higher than conventional but full life cycle costs may be lower	

Table 4.3 Comparison of Microfiltration and Conventional Drinking Water Treatment Processes

Microfiltration	Conventional
Advantages	
Provides complete/fail-safe bacteria and parasitic disease protection (with appropriate integrity monitoring technology)	Provides good protection if properly/skilfully operated
Can be operated by semi-skilled personnel working ˉ2 hours per week	Requires skilled operator attention at least several hours per day
Requires little or no chemicals or sophisticated engineering parts	Requires careful storage/handling/use of reactive chemicals and maintenance inventory and maintenance skills
Produces easily disposed chemically uncontaminated waste stream	Produces waste stream requiring treatment before discharge in addition to solids disposal
Generally produces lesser amounts of disinfection by-products e.g. THMs	Requires use chlorine or other powerful disinfectant and longer contact/storage times producing more by-products
Requires small area building with a simple concrete pad and more modest tankage	Requires larger more complex building and large tanks
Easily expanded to meet non-forecast demand	Is generally built to appropriate size for full projected plant life but can be modularized with appropriate planning.
Shortened pilot/construction elapsed time requirements	Often requires multi-season pilot and longer construction lead time
Copes automatically with most raw water quality changes	Difficult to operate well, or automate for, with rapidly changing raw water quality
Reduced waste disposal costs	Requires increased waste disposal investment and costs
Capital cost much lower than full conventional treatment in all except very large and very small plant sizes	Up to two fold increased capital requirements
Disadvantages	
Requires better quality raw water which does not need large chemical adjustment	Capable of treating poor quality raw water -
Does not reduce water colour without extra expense/processing	Can reduce water colour
Requires moderately expensive filter replacement at 3 to 10 year basis - can be guaranteed	Requires continued chemical supply
Requires slightly (5-10%) increased pumping costs	
May not cope easily with severe algae or zebra mussel problems	

Table 4.5 Comparison of Slow Sand Filtration and Conventional Drinking Water Treatment Processes

Slow Sand	Conventional
Advantages	
Provides good protection from bacteria, viruses and parasitic infections	Provides good protection if properly attended and skillfully operated
Can be operated by semi-skilled personnel working ~2-4 hours per week	Requires skilled operator attention for at least several hours per day
Requires little or no chemicals nor sophisticated engineering parts nor skilled trades work input	Requires careful storage/handling/use of reactive chemicals and maintenance inventory and on-site maintenance skill
Produces, no waste stream - only small amount of dirty sand need recycling or disposal	Produces waste stream requiring treatment before discharge and solids disposal
Disadvantages	
Requires good to fairly good quality raw water	Can operate with higher organics and other contaminant levels
Requires large area shallow tanks in a heated building	Smaller building needed but more expensive processing equipment required
Does not reduce water colour without extra expense/processing	Can reduce water colour
Does not cope well with algae	
Requires long period pilot investigation	
Probable slightly higher capital cost compensated over plant life by sharply reduced chemicals requirement and reduced operator requirements	

TABLE 5.1: COST ESTIMATE FOR UPGRADE OF WATER TREATMENT FACILITIES: THM STUDY POPULATION BASED FLOW*

Community	**Population**	**Flow (a)**	**Treatment Strategy**		**Annual Cost (b)**		
		ML/d			Capital	O&M	Total
Hudson	500	0.30	Microfiltration + Nanofiltration + Chlorine Disinfection	Total	51,000	102,000	153,000
			Slow Sand Filtration + Chlorine Disinfection + Ammoniation	Total	150,000	51,000	201,000
			Full Conventional Treatment		52,000	126,000	178,000
Sioux Lookout	5,000	3.00	Microfiltration + Nanofiltration + Chlorine Disinfection	Total	228,000	526,000	754,000
			Microfiltration + Chlorine Disinfection + Ammoniation	Total	128,000	197,000	325,000
			Full Conventional Treatment		119,000	120,000	239,000
Red Lake	2,100	1.26	Pretreatment + Nanofiltration + Chlorine Disinfection	Total	74,000	239,000	313,000
			Microfiltration + Chlorine Disinfection + Ammoniation	Total	73,000	83,000	155,000
			Full Conventional Treatment		85,000	106,000	191,000
Cochenour	550	0.33	Microfiltration + Nanofiltration + Chlorine Disinfection	Total	53,000	108,000	161,000
			Microfiltration + Chlorine Disinfection + Ammoniation	Total	43,000	42,000	85,000
			Full Conventional Treatment		52,000	205,000	256,000

5. ALTERNATIVE TREATMENT STRATEGY COSTS

Cost estimation for water treatment facilities is complex and involves a number of steps toward development of an as-constructed cost. Initial cost estimation feasibility studies of potential treatment alternatives at the project pre-planning stage are normally expected to be accurate to within plus or minus 30%.

Cost estimates for both Capital Costs and Operation and Maintenance (O&M) Costs have been completed for this report. Given the remote locations of many of the water supplies, and the need for site-specific inspection and preliminary bench testing, the estimates presented here will be expected to be within 45 %.[22] Following completion of the site-specific studies, the cost estimation accuracy would be expected to be further refined to within 30%. The next step would be the specific project design costs, again with evaluation of alternatives, to bring the estimates to within 10%.[23]

Table 5.1 gives the annualized capital and O&M costs for the 12 communities using a nominal population based design flow requirement of 400 L/day, and Table 5.2 gives the same information for design flows based on the questionnaire replies from each location.[24]

Following discussions with MOEE an additionally conservative approach to the nanofiltration cost estimates prepared by Delcan Corporation (included in Appendix D) has been applied to Tables 5.1 and 5.2. A 2.5 factor increase has been applied to the nanofiltration component of the O&M costs. This adjustment assumes more frequent membrane replacement; additional electrical pumping costs; chemical cleaning and waste cleaner disposal; and, the extra level of operational and maintenance skills needed for the nanofiltration process equipment and associated monitoring instrumentation (e.g. particle counting).

It should also be noted that, specifically for the membrane cost estimates, a rate of inflation would not need to be reflected on the projected capital costs because membrane costs are decreasing. The development costs for this technology have essentially been paid off.

---

[22] Adequate pilot studies should cost less than 10% of the estimated final capital dollars and will be required in most cases

[23] It should be noted that the two supply alternatives for Thunder Bay - Loch Lomond and expansion of the Bare Point WTP will require different additional capital costing issues. For expansion of the Bare Point option, supply balancing, a trunk main and booster pumping is needed in addition to pumping at the plant. For the Loch Lomond alternative no pumping is required.

[24] Appendix D contains details of the derivation of Tables 5.1 and 5.2 in addition to baseline information of the cost estimation carried out for the identified treatment alternatives.

TABLE 5.1: COST ESTIMATE FOR UPGRADE OF WATER TREATMENT FACILITIES: THM STUDY POPULATION BASED FLOW*

Community	Population	Flow (a) ML/d	Treatment Strategy	Annual Cost (b) Capital	O&M	Total
Balmertown	1,600	0.96	Pretreatment + Nanofiltration + Chlorine Disinfection Total	62,000	112,000	174,000
			Microfiltration + Chlorine Disinfection + Ammoniation Total	63,000	67,000	130,000
			Full Conventional Treatment	79,000	116,000	195,000
Port Carling	800	0.48	Pretreatment + Nanofiltration + Chlorine Disinfection Total	43,000	149,000	192,000
			Microfiltration + Chlorine Disinfection + Ammoniation	48,000	44,000	92,000
			Chlorine Disinfection + Ammoniation	9,000	25,000	33,000
			Chlorine Dioxide Disinfection	15,000	30,000	45,000
			Direct Filtration	24,000	42,000	66,000
Thunder Bay (Loch Lomond) [c]	45,000	22.70	Chlorine Dioxide Disinfection	330,000	331,000	662,000
			Chlorine Disinfection + Ammoniation	123,000	249,000	371,000
			Microfiltration + Chlorine Disinfection + Ammoniation	760,000	829,000	1,588,000
			Direct Filtration	1,001,000	497,000	1,498,000
Thunder Bay (Bare Point) [c]	45,000	22.70	Microfiltration + Chlorine Disinfection	757,000	746,000	1,503,000
			Direct Filtration	1,001,000	497,000	1,498,000

* Differences in Annual Costs may be noted for systems with similar flows, this reflects the fact that consideration of local factors has been taken into account

Assumptions:

(a) estimate based on existing population, consumption of 400L/person/day; additional 50% for fire

(b) all cost in 1997 Canadian dolars, US$ to CND$ conversion of 1.4, capital cost amortized over 20 years at 7%

(c) it should be noted that the two supply alternatives for Thunder Bay - Loch Lomond and expansion of Bare Point WTP will require different additional capital costing issues, for the expansion of the Bare Point option, supply balancing, a trunk main and booster pumping is needed in addition to pumping at the plant; for the Loch Lomond alternative no pumping is required

Other: This estimate is only preliminary. Potential savings may be realised following site examination especially in the use of existing equipment/facilities

TABLE 5.1: COST ESTIMATE FOR UPGRADE OF WATER TREATMENT FACILITIES: THM STUDY POPULATION BASED FLOW*

Community	**Population**	**Flow (a)** ML/d	**Treatment Strategy**		**Annual Cost (b)**	
				Capital	O&M	Total
Madsen	300	0.18	Pretreatment + Nanofiltration + Chlorine Disinfection Total	31,000	89,000	120,000
			Microfiltration + Chlorine Disinfection + Ammoniation Total	38,000	30,000	-
			Full Conventional Treatment	39,000	104,000	143,000
McFarlane Lake	300	0.18	Chlorine Disinfection + Ammoniation	7,000	13,000	21,000
			Microfiltration + Chlorine Disinfection + Ammoniation Total	38,000	30,000	68,000
			Slow Sand Filtration + Chlorine Disinfection + Ammoniation Total	94,000	46,000	140,000
			Direct Filtration	12,000	34,000	45,000
Vermillion Bay	500	0.30	Chlorine Dioxide Disinfection	10,000	33,000	43,000
			Chlorine Disinfection + Ammoniation	8,000	19,000	27,000
			Microfiltration + Chlorine Disinfection + Ammoniation	42,000	35,000	77,000
			Direct Filtration	17,000	44,000	61,000
Wendover	850	0.51	Microfiltration + Nanofiltration + Chlorine Disinfection Total	61,000	123,000	184,000
			Microfiltration + Chlorine Disinfection + Ammoniation Total	49,000	48,000	97,000
			Full Conventional Treatment	65,000	127,000	192,000

TABLE 5.2: COST ESTIMATE FOR UPGRADE OF WATER TREATMENT FACILITIES: THM STUDY BASED ON QUESTIONNAIRE FLOW*

Community	**Population**	**Flow** ML/d	**Treatment Strategy**	**Annual Cost (b)** Capital	 O&M	 Total
Madsen	300	0.17	Pretreatment + Nanofiltration + Chlorine Disinfection			
			Total	30,000	84,000	114,000
			Microfiltration + Chlorine Disinfection + Ammoniation			
			Total	26,000	28,000	54,000
			Full Conventional Treatment	38,000	99,000	137,000
McFarlane Lake	240	0.21	Chlorine Disinfection + Ammoniation	8,000	15,000	22,000
			Microfiltration + Chlorine Disinfection + Ammoniation			
			Total	28,000	31,000	60,000
			Slow Sand Filtration + Chlorine Disinfection + Ammoniation			
			Total	49,000	34,000	83,000
			Direct Filtration	13,000	37,000	51,000
Vermillion Bay	550	0.48	Chlorine Dioxide Disinfection	15,000	30,000	45,000
			Chlorine Disinfection + Ammoniation	9,000	25,000	34,000
			Microfiltration + Chlorine Disinfection + Ammoniation			
			Total	44,000	39,000	83,000
			Direct Filtration	25,000	42,000	67,000
Wendover	850	0.62	Microfiltration + Nanofiltration + Chlorine Disinfection			
			Total	75,000	128,000	203,000
			Microfiltration + Chlorine Disinfection + Ammoniation			
			Total	50,000	59,000	109,000
			Full Conventional Treatment	71,000	113,000	184,000

TABLE 5.2: COST ESTIMATE FOR UPGRADE OF WATER TREATMENT FACILITIES: THM STUDY BASED ON QUESTIONNAIRE FLOW*

Community	Population	Flow ML/d	Treatment Strategy		Annual Cost (b) Capital	O&M	Total
Hudson	500	0.083	Microfiltration + Nanofiltration + Chlorine Disinfection	Total	28,000	46,000	75,000
			Slow Sand Filtration + Chlorine Disinfection + Ammoniation	Total	44,000	15,000	60,000
			Full Conventional Treatment		24,000	95,000	119,000
Sioux Lookout	5,000	7.87	Microfiltration + Nanofiltration + Chlorine Disinfection	Total	547,000	1,178,000	1,726,000
			Microfiltration + Chlorine Disinfection + Ammoniation	Total	359,000	517,000	876,000
			Full Conventional Treatment		311,000	287,000	599,000
Red Lake	2,060	3.11	Pretreatment + Nanofiltration + Chlorine Disinfection	Total	142,000	495,000	637,000
			Microfiltration + Chlorine Disinfection + Ammoniation	Total	151,000	204,000	355,000
			Full Conventional Treatment		123,000	125,000	248,000
Cochenour	700	1.19	Microfiltration + Nanofiltration + Chlorine Disinfection	Total	116,000	192,000	307,000
			Microfiltration + Chlorine Disinfection + Ammoniation	Total	90,000	74,000	163,000
			Full Conventional Treatment		83,000	117,000	200,000

TABLE 5.2: COST ESTIMATE FOR UPGRADE OF WATER TREATMENT FACILITIES: THM STUDY BASED ON QUESTIONNAIRE FLOW*

Community	Population	Flow ML/d	Treatment Strategy	Annual Cost (b)		
				Capital	O&M	Total
Balmertown	1,570	6.51	Pretreatment + Nanofiltration + Chlorine Disinfection Total	283,000	1,010,000	1,293,000
			Microfiltration + Chlorine Disinfection + Ammoniation Total	302,000	428,000	730,000
			Full Conventional Treatment	236,000	261,000	497,000
Port Carling	800	0.58	Pretreatment + Nanofiltration + Chlorine Disinfection Total	51,000	165,000	216,000
			Microfiltration + Chlorine Disinfection + Ammoniation Total	53,000	46,000	99,000
			Chlorine Disinfection + Ammoniation	9,000	27,000	36,000
			Chlorine Dioxide Disinfection	18,000	29,000	47,000
			Direct Filtration	29,000	44,000	73,000
Thunder Bay (Loch Lomond) [(c)]	45,000	26.50	Chlorine Dioxide Disinfection	330,000	387,000	717,000
			Chlorine Disinfection + Ammoniation	283,000	290,000	573,000
			Microfiltration + Chlorine Disinfection + Ammoniation Total	1,699,000	1,160,000	2,860,000
			Direct Filtration	1,001,000	580,000	1,581,000
Thunder Bay (Bare Point) [(c)]	45,000	26.50	Microfiltration + Chlorine Disinfection Total	1,696,000	1,064,000	2,760,000
			Direct Filtration	1,001,000	580,000	1,581,000

* Differences in Annual Costs may be noted for systems with similar flows; this reflects the fact that consideration of local factors has been taken into account

Assumptions:

(b) all cost in 1997 Canadian dolars, US$ to CND$ conversion of 1.4, capital cost amortized over 20 years at 7%

(c) it should be noted that the two supply alternatives for Thunder Bay - Loch Lomond and expansion of Bare Point WTP will require different additional capital costing issues, for the expansion of the Bare Point option, supply balancing, a trunk main and booster pumping is needed in addition to pumping at the plant; for the Loch Lomond alternative no pumping is required

Other: This estimate is only preliminary. Potential savings may be realised following site examination especially in the use of existing equipment/facilities

U.S. Environmental Protection Agency, Point-Of-Use Treatment to Control Organic and Inorganic Contaminants in Drinking Water, Water Engineering Research Laboratory, Center for Environmental Research Information, Cincinnati, OH, U.S.A., EPA-600/S2-85-112, January 1986.

White, G.C., Handbook of Chlorination, 2nd ed., New York, U.S.A.: Van Nostrand Reinhold, 1986.

6. REFERENCES

Edmonds, A, personal correspondence and communication, 1996

James M. Montgomery, Consulting Engineers Inc., Water Treatment Principles and Design, U.S.A.: John Siley & Sons, 1985.

Logsdon, G.C., Mason, L., Stanley, J.B. Jr., "*Troubleshooting an Existing Treatment Plant*", AWWA Seminar Proceedings - Filtration: Meeting New Standards, June 1988, pp. 109-125.

McGuire, M., "*Trihalomethanes,*" in Water Treatment Plant Operation: A Field Study Training Program, VII, 3rd ed, ed. by K. Kerri. U.S.A.: California State University, Sacramento Foundation, 1994.

Memtec American Corporation, *Memcor - Application Bulletin A1001 'CMF Application Parameters - Potable Water*', 1996. Information accessed off of the Internet.

Ontario, Ministry of the Environment and Energy, Environmental Bill of Rights, "*Proposal to Adopt the Canadian Drinking Water Quality Guideline for Trihalomethanes as an Ontario Drinking Water Objective*", November 1995.

Patania, N.L. et al., "*Removal of Cryptosporidium, Giardia and Particles by Granular Media Filtration in Pilot Studies*", AWWA Annual Conference, Anaheim, CA, U.S.A., June 1995.

Symons, J. M., et al., Treatment Techniques for Controlling Trihalomethanes in Drinking Water, Drinking Water Research Division, Municipal Environmental Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, OH, U.S.A., EPA-600/2-81-156, September 1981.

U.S. Environmental Protection Agency, Technologies for Upgrading Existing or Designing New Drinking Water Treatment Facilities, Office of Drinking Water, Center for Environmental Research Information, Cincinnati, OH, U.S.A., EPA-625/4-89-023, March 1990.

APPENDIX A
SYSTEM DATA

Supply System	Data Description	Data Source
McFarlane Lake	• MOEE THM Survey Data • Table: Raw Water and Treated Water Demand - July 1996 • Averaging Report - August 1994 to July 1996 [includes: flows, raw water quality (chemical and bacteriological), distribution system (bacteriological), treated water quality (chemical and aesthetic), disinfection] • Table: Chlorine Residuals in Distribution - 1995 to 1996 • Ontario Drinking Water Surveillance Program - THM Survey Data - Monitoring Period: 1995 to 1996 • MOEE Central Laboratory - Final Analytical Results - sample dates: 10/07/96 and 27/11/95	• McFarlane Lake Staff • McFarlane Lake Staff • McFarlane Lake Staff • McFarlane Lake Staff • MOEE •
Port Carling	• MOEE THM Survey Data • Certificate of Approval No 7-0087-77-006 • File on Disk: WPC95.xls [Port Carling 1995 data, including: flows, finished water quality, distribution system water quality • File on Disk: WBBBS95.xls [Bracebridge Water Plant 1995 data, including: flows, raw water quality, finished water quality, distribution system water quality] • Ontario Drinking Water Surveillance Program - THM Survey Data - Monitoring Period: 1995 to 1996	• Port Carling Staff • MOEE • Port Carling Staff • Port Carling Staff • MOEE
Red Lake	• MOEE THM Survey Data • Amended Certificate of Approval No. 7-1213-95-967 • Ontario Drinking Water Surveillance Program - Summary Report of Total Trihalomethanes Concentrations - 1993 to 1996 • Ontario Drinking Water Surveillance Program - Monthly Max./Min./Ave. Flow Data - 1993 to 1996 • Drinking Water Surveillance Program - Draft Data Summary Report for 1993 to 1994 • Water Treatment Plant - Compliance Inspection Report	• MOEE • MOEE • MOEE • MOEE • MOEE • MOEE
Sioux Lookout	• MOEE THM Survey Data • Certificate of Approval for Extensions: Preliminary Approval - 1979; 1982 - No. 7-0191-82-006; 1982; 1983; • 1994 and 1995 monthly water demand, chlorine dosage, chlorine average residual, and turbidity • 1995 and 1996 monthly laboratory test results • Water Treatment Plant - Compliance Inspection Report 1995 • Ontario Drinking Water Surveillance Program - THM Survey Data - Monitoring Period: 1995 to 1996	• Sioux Lookout Staff • MOEE • Sioux Lookout Staff • • MOEE • MOEE

Table A.1: Data Description and Sources

Supply System	Data Description	Data Source
Balmertown	• MOEE THM Survey Data • Monthly Water Quality Report in US Gallons (1995) - file on disk • Water Quality Summary Table 1995 - file on disk • Amendment to the Certificate of Approval No 7-0790-90-916	• Placier Dome Staff • Placier Dome Staff • Placier Dome Staff • MOEE
Cochenour	• MOEE THM Survey Data • Ontario Drinking Water Surveillance Program - Summary Report of Total Trihalomethanes Concentrations - 1993 to 1996 • Ontario Drinking Water Surveillance Program - Monthly Max./Min./Ave. Flow Data - 1993 to 1996 • Drinking Water Surveillance Program - Draft Data Summary Report for 1993 to 1994 • Water Treatment Plant - Compliance Inspection Report - 1994	• MOEE • MOEE • MOEE • MOEE • MOEE
Hudson	• MOEE THM Survey Data • Ontario Drinking Water Surveillance Program - THM Survey Data - Monitoring Period: 1995 to 1996 • Water Treatment Plant - Compliance Inspection Report - 1994 [includes: Figure: Plant Layout and Table: Water Treatment Plant Flows - 1994] • Environment Ontario Final Report - Hudson WTP Treated - sample dates 31/08/94 and 02/03/94 • Certificate of Approval No. 7-0775-84-856 • Water Treatment Plant - Compliance Inspection Report - 1993	• Hudson Staff • MOEE • MOEE • MOEE • MOEE • MOEE
Madsen	• MOEE THM Survey Data (2) • Ontario Drinking Water Surveillance Program - Summary Report of Total Trihalomethanes Concentrations - 1993 to 1996 • Ontario Drinking Water Surveillance Program - Monthly Max./Min./Ave. Flow Data - 1993 to 1996 • Drinking Water Surveillance Program - Draft Data Summary Report for 1993 to 1994 • Water Treatment Plant - Water Inspection Report - 1995	• Madsen Staff / MOEE • MOEE • MOEE • MOEE • MOEE

Supply System	Data Description	Data Source
Thunder Bay - Bare Point	• MOEE THM Survey Data	• City of Thunder Bay Staff
	• Certificate of Approval: Bare Point Plant Expansion No. 7-3076-76-001; Raw Water Intake 7-0748-90-006	• MOEE
	• The City of Thunder Bay - Water Treatment Plant And Water Pollution Control Plant - 1995 - Annual Report	• City of Thunder Bay Staff
	• Ontario Drinking Water Surveillance Program - Summary Report of Total Trihalomethanes Concentrations 1990 to 1996	• MOEE
	• Evaluation criteria identified in Phase I	• supplied City of Thunder Bay Staff
	• Drinking Water Surveillance Program - Draft Data Summary Report for 1993 and 1994	• MOEE
Thunder Bay - Loch Lomond	• MOEE THM Survey Data	• City of Thunder Bay Staff
	• Certificate of Approval: Hodder Avenue Pumping Station; Hodder Avenue Standpipe; Loch Lomond Corrosion Control No. 7-0995-78-791; Loch Lomond Sodium Silicate Facilities No. 7-0290-86-006; Neebing Booster Pump House and Stand-by Diesel Generator No. 7-0796-81-006; Modifications to Neebing Booster Pump House No. 7-1607-89-006; McIntyre Reservoir and Pumping Station; Chamberlain Street Pumping Station; Sewage Works Approval	• MOEE
	• Ontario Drinking Water Surveillance Program - Summary Report of Total Trihalomethanes Concentrations	• MOEE
	• Drinking Water Surveillance Program - Draft Data Summary Report for 1993 and 1994	• MOEE
	• The City of Thunder Bay - Water Treatment Plant And Water Pollution Control Plant - 1995 - Annual Report	• City of Thunder Bay Staff
Wendover	• MOEE THM Survey Data	• Wendover Staff
	• Table: Water Consumption - 1991 to 1994	• Township of North Plantagenet
	• Table: Chemical Results - Average Yearly Values for 1991 to 1994	• Township of North Plantagenet
	• Table: Bacteriological Results - findings for 1989 to 1994	• Township of North Plantagenet
	• Table: Chlorine Used and Chlorine Residual at Supply - 1995 to 1996	• McNeely Engineering Consultants Ltd.
	• Letter from McNeely Engineering Consultants Ltd. [description of Wendover Treatment Plant Conceptual Design]	• MOEE
	• Ontario Drinking Water Surveillance Program - THM Survey Data - Monitoring Period: 1995 to 1996	• MOEE
Vermilion Bay	• MOEE THM Survey Data	• Vermilion Bay Staff
	• Water Treatment Plant - Compliance Inspection Report	• MOEE

APPENDIX B
GROUNDWATER PRELIMINARY ASSESSMENT

Wendover

The community of Wendover is located in North Plantagenet Township[3] on the Ottawa River in south eastern Ontario at 45°34' N,75°07' W [1]. The NTIS topographic sheet covering the region is 31 G/11. The bedrock in the area is primarily limestone [9] which may allow the development of high capacity wells, and should be investigated further. No major sand or gravel deposits are indicated nearby[7, 11], in fact the region is a clay plain, which would tend to protect any bedrock aquifer from surficial contamination.

Balmertown

The community of Balmertown is located north of Dryden on Red Lake at 51°04' N, 93°44' W[1]. Nearby are the communities of Red Lake, Cochenour, and Madsen, which are also the subject of this report. Since the distances between these towns are 7 km or less, the possibility for cooperation in the development of a water supply exists. The topographic map sheet for this area is 52 N/4 (Madsen is on the adjacent sheet 52 K/13). The topographic map indicates significant areas near each town labelled "mine waste". These areas are potential sources of groundwater contamination, and any development of groundwater supply would have to consider them. Bedrock in the area is all of early Precambrian origin with felsic and mafic metavolcanics predominating[5], and is not likely to yield high capacity wells. Surficial geology mapping indicates that the soil in the immediate area is glacial till or bare rock, which would not yield an overburden well, but approximately 10 km northeast of Red Lake, a small sand and gravel deposit is indicated as part of a moraine[6]. A more detailed map showing Madsen (5 km south of Red Lake, or 12 km from Balmertown) shows another series of glacial delta and glacial outwash sand and gravel deposits[12]. At least one sand/gravel pit exists on this feature which is in three parts covering an area approximately 10 km by 20 km. A significant pipeline would be necessary to develop this as a groundwater supply; however, this may be desirable in order to isolate the water supply from the mine tailings around the towns.

Port Carling

The town of Port Carling is located between Lake Rosseau and Lake Muskoka at 45°07' N, 79°35' W[1]. The relevant topographic map sheet is 31 E/4. Bedrock in Port Carling is late Precambrian felsic granite to the east and middle Precambrian clastic metasediments to the west[9]. Unless the clastic metasediments prove to be high permeability sandstone, a high yield bedrock supply is unlikely. Surficial geology mapping indicates that the only potential groundwater supply is a moraine sand/gravel deposit approximately 10 km east of Port Carling[7, 10]. A more detailed map indicates two lobes aligned north-south between the communities of Ufford and Milford Bay, these are identified as sand and gravel resources[13].

TECHNICAL MEMORANDUM

From: Ted Barton and Mike Hulley

To: Ken Roberts

Re: **Groundwater Resources Potential for Selected Ontario Communities**

XCG Consultants Limited has been retained by the Ministry of the Environment to provide a brief assessment of the potential development of community groundwater supplies for 12 Ontario communities currently serviced by surface water supplies. It is our understanding that, due to the presence of trihalomethanes in the treated water supply, that a decision to either upgrade the existing plant or to pursue development of a groundwater supply must be made.

The purpose of this technical memorandum is to provide a screening for each community using available mapping. The screening procedure used was not exhaustive, as resources such as hydrogeological reports and water well records were not used. However, these may be used in any subsequent phase if the potential for groundwater supplies looks promising.

Both overburden and bedrock wells are considered. Bedrock wells of sufficient capacity to service would require a sedimentary bedrock which is permeable on a regional scale such as a limestone or sandstone. Although igneous and metamorphic wells can provide single-home water supplies, hydraulic conductivities are not high enough to provide the required supply. Overburden wells would require a large-scale sand or gravel deposit.

Vermilion Bay

The community of Vermilion Bay is located west of Dryden at 49°50' N, 93°22' W [1] in Langton Township[2,3] on the north edge of Eagle Lake. The NTIS topographic map sheet covering the area is 52 F/14 [4]. Bedrock is early Precambrian consisting of granite and basalt[5] which is not likely to yield high capacity wells. Surficial geology mapping indicates a large scale sand and gravel moraine through Vermilion Bay from the northwest to the southeast[6,7]. A regional map indicates that this sand and gravel deposit is of glaciofluvial origin and is approximately 50 km in length and varies from 0.5 to 2 km in width. More than 25 sand and gravel pits are indicated along the length of the deposit[8]. Beach forms of glaciolacustrine origin are also indicated adjacent to the deposit. This feature is worth further investigation as a potential groundwater supply, as large yields would be possible where the deposit is thick.

and sandstone[5]. If either of these are present in a highly permeable state, then bedrock wells may be possible. This could be verified by detailed examination of water well records in the area. Surficial geology mapping does not indicate any large sand/gravel deposits near McFarlane Lake[6]. A more detailed map indicates that the town is located on a silty sand deposit[16]. Water well records would indicate typical depths and yields. Also, approximately 8 km southeast of the town is a glacial outwash deposit which is currently hosting at least 6 sand pits. Several buildings, probably residential, are indicated over this deposit. Their water well records and experiences would help in evaluating the potential for a high yield well.

Thunder Bay

The city of Thunder Bay is located on the shore of Lake Superior at 48°27' N, 89°10' W[1]. The city currently has two water supplies, one at Bare Point to the north, and the other at Loch Lomond to the south. Bedrock geology mapping indicates middle Precambrian rock of the Animikie Group, changing to late to middle Precambrian mafic rock to the south[5]. High yield bedrock wells are unlikely, although one of the possible members of the Animikie group is sandstone. Detailed surficial geology mapping indicates many sand/gravel pits both north and west of town[17]. Finding a protected groundwater supply may be a challenge in an urban area, but it may be possible, as there are many sand/gravel and sand/silt deposits both of glacial and lacustrine origin around the city.

Summary

Location	Potential for surficial or bedrock groundwater supply
Vermilion Bay	**Moderate**, warrants a more detailed review.
Wendover	**Moderate**, warrants a more detailed review.
Balmertown	**Low**, due to potential contamination and remoteness of supply.
Port Carling	**Low**, due to remoteness of potential supply and capacity required.
Hudson	**Moderate**, warrants a more detailed review.
Sioux Lookout	**Moderate**, warrants a more detailed review.
Red Lake	**Low**, due to potential contamination and remoteness of supply.
Cochenour	**Low**, due to potential contamination and remoteness of supply.
Madsen	**Low**, due to potential contamination and remoteness of supply.
McFarlane Lake	**Moderate**, warrants a more detailed review.
Thunder Bay	**Low**, due to capacity requirements.

Hudson

The community of Hudson is located east of Dryden, and approximately 15 km west of Sioux Lookout. There is therefore the potential for development of a joint water supply for the two communities. The relevant topographic map sheet is 52 K/1, and the town is located at 50°05' N, 92°10' W[1]. The bedrock in the area is early Precambrian, both felsic igneous and mafic metavolcanic; hence a bedrock groundwater supply is unlikely. Surficial geology mapping indicates sand following the shore of Lost Lake, passing under the town[6]. A more detailed mapping indicates this is a sand and gravel deposit of glaciofluvial origin punctuated with bedrock knobs[14]. If an area of sufficient depth can be found, a high capacity well could be developed.

Sioux Lookout

The community of Sioux Lookout is located east of Dryden at 50°06' N, 91°55' W[1]. The relevant topographic map sheets are 52 J/4 and 52 K/1. Bedrock geology is the same as described for Hudson. Surficial geology mapping indicates a large sand deposit east of town with an esker formation running from northwest to southeast[6]. A more detailed mapping indicates two major sand and gravel deposits both under the town and immediately northeast of town covering an area approximately 10 km by 12 km. The deposits are mixed sand/gravel and sand/silt of glaciofluvial and glaciolacustrine origin[15]. At least 12 active sand pits are identified on the map. This area should be investigated further as a potential water supply. There is another, larger deposit south of the Sturgeon River, east of the town as well.

Red Lake

Red Lake is located north of Dryden at 51°01' N, 93°50' W[1]. This region was discussed above with Balmertown.

Cochenour

Cochenour is located north of Dryden at 51°05' N, 93°48' W[1]. This region was discussed above with Balmertown.

Madsen

Madsen is located north of Dryden at 50°58' N, 93°55' W[1]. This region was discussed above with Balmertown.

McFarlane Lake

McFarlane Lake is located south of the city of Sudbury at 46°26' N, 80°57' W[1]. The relevant topographic sheet is 41 I/7. Bedrock in this area is complex. The geological map indicates middle Precambrian of the huronian supergroup. High capacity bedrock wells are not likely, although two members of the huronian supergroup are limestone

15. Marchington Lake, NTS 52J/SW, Data Base Map, Northern Ontario Engineering Geology Terrain Study, Ontario Geological Survey, Ministry of Natural Resources, Map 5114, 1:100 000, 1989.

16. Sudbury, NTS 41I/SE, Data Base Map, Northern Ontario Engineering Geology Terrain Study, Ontario Geological Survey, Ministry of Natural Resources, Map 5003, 1:100 000, 1978.

17. Thunder Bay, NTS 52A/SW, Data Base Map, Northern Ontario Engineering Geology Terrain Study, Ontario Geological Survey, Ministry of Natural Resources, Map 5047, 1:100 000, 1979.

References

1. Gazetteer of Canada, 4th edition, Canadian Government Publications Centre, Supply and Services Canada, Ottawa, 1988.
2. Geographic Townships in the Province of Ontario, Map 28, Ministry of Natural Resources, 1"=25 miles, 1981.
3. The Southern Part of the Province of Ontario, Department of Lands and Forests, 1"=8 miles, 1957.
4. NTIS Topographic Series, Ministry of Natural Resources, Various dates.
5. Geological Highway Map - Northern Ontario, Ontario Geological Survey, Ministry of Natural Resources, Map 2440, 1:600 000, 1980.
6. Surficial Geology of Northern Ontario, Ontario Geological Survey, Ministry of Northern Development and Mines, Map 2518, 1:1 200 000, 1987.
7. Industrial Minerals of Ontario, Ontario Geological Survey, Ministry of Natural Resources, Map P.2591, 1:1 500 000, 1983.
8. Blue Lake, NTS 52F/NW, Data Base Map, Northern Ontario Engineering Geology Terrain Study, Ontario Geological Survey, Ministry of Natural Resources, Map 5058, 1:100 000, 1980.
9. Geological Highway Map - Southern Ontario, Ontario Geological Survey, Ministry of Natural Resources, Map 2441, 1:800 000, 1980.
10. Physiography of Southern Ontario, Ontario Geological Survey, Ministry of Natural Resources, Map P.2715, 1:600 000, 1984.
11. Ottawa, NTS 31 G/SW and part of 31 G/NW, Data Base Map, Southern Ontario Engineering Geology Terrain Study, Ontario Geological Survey, Ministry of Natural Resources, Map 5513, 1:100 000, 1990.
12. Pakwash Lake, NTS 52K/NW, Data Base Map, Northern Ontario Engineering Geology Terrain Study, Ontario Geological Survey, Ministry of Natural Resources, Map 5107, 1:100 000, 1989.
13. Ontario Mineral Potential, Huntsville Sheet, Ontario Geological Survey, Ministry of Natural Resources, Map 1976-4, 1" to 4 miles, 1976.
14. Vaughan Lake, NTS 52K/SE, Data Base Map, Northern Ontario Engineering Geology Terrain Study, Ontario Geological Survey, Ministry of Natural Resources, Map 5110, 1:100 000, 1989.

supply may be available, the next steps toward development of a municipal well supply would include investigative drilling, and quality and capacity testing.

4. Finally, given the availability of a suitable supply, capital works for the development of an operational well supply would be undertaken.

DETAILED GROUNDWATER SOURCE REVIEW

Objectives:

1. to establish the potential of a municipal groundwater water supply, of adequate quality and quantity, and if possible
2. to determine the requirements of any necessary field activities for the final assessment/development of the groundwater supplies.

Proposed Steps for a Detailed Review:

1. **Procurement of Water Well Records**: For each community with a moderate potential for municipal groundwater supplies, the available MOEE water well records will need to be obtained for the relevant Concessions, Lot Numbers, and municipalities.

2. **Analysis of Water Well Records**: Once the specific well records are obtained, they should be reviewed and an estimate made of the magnitude of the available groundwater supply.

   In addition to a description of yield, the water well records will also provide an indication of surficial geology, depth to bedrock, and groundwater elevations. If the water well records are available in a digital format they can be processed using specifically developed software.

3. **Formulation of Recommendations Concerning Field Activities**: If the analysis of the MOEE water well records indicates that an adequate municipal groundwater

APPENDIX C
RED LAKE AND WENDOVER PROPOSED TREATMENT FACILITIES

- a new underground reservoir with a storage capacity of 450 m^3:
- installation of the four (4) existing high lift pumps above the reservoir;
- a two cell backwash waste-water settling tank with two submersible pumps, one rated at 20 L/s @ a T.D.H. of 8.2 m for pumping sludge and the other rated at 6 L/s @ 4.7 m T.D.H. for transferring backwash wastewater from the retention cell to the settling cell;
- replace existing 75 kW diesel standby generator with a 125 kW generator;

including station pipework, valves, meters, heating and ventilation, electrical and control systems all in accordance with Design Brief, dated July 1996, final plans and specifications prepared by Wardrop Engineering Inc., Consulting Engineers, subject to the following Terms and Conditions.

You are hereby notified that this approval is issued to you subject to the terms and conditions outlined below:

TERMS AND CONDITIONS

DEFINITIONS

(1) "certificate" means this entire certificate of approval document, issued in accordance with Section 52 of the *Ontario Water Resources Act*, and includes any schedules;

(2) "Director" means any Ministry employee appointed by the Minister pursuant to section 5 of the *Ontario Water Resources Act*;

(3) "Ministry" means the Ontario Ministry of Environment and Energy;

(4) "Regional Director" means the Regional Director of the Northern Ontario Region of the Ministry;

(5) "District Manager" means the District Manager of the Kenora District Office of the Ministry's Northern Ontario Region;

(6) "Owner" means Township of Red Lake and includes its successors and assignees;

(7) "works" means the water works described in the Owner's application, this certificate and in the supporting documentation referred to herein, to the extent approved by this certificate;

(8) "water treatment plant" means the entire water treatment system, including the water intake facilities;

(9) "water supply system" means all of the facilities and auxiliaries for the collection, treatment, storage and distribution of water from the source of supply to the service connection of the ultimate consumer;

[redacted]

Ministry of Environment and Energy
Ministère de l'Environnement et de l'Énergie
Ontario

**AMENDED CERTIFICATE OF APPROVAL
WATER
NUMBER 7-1213-95-967**

Township of Red Lake
Box 308, 117 Howey Street
Red Lake, Ontario
P0V 2M0

You have applied in accordance with Section 52 of the Ontario Water Resources Act for approval of:

upgrading and expansion of the existing water works located on Part 1, plan KR1615, in the Township of Red Lake, as follows:

Upgrading of the Existing Water Pumping Station (Phase 1)

- replace existing pumps with four (4) vertical turbine pumps, three duty and one standby, each rated at 20.0 L/s at a T.D.H. of 70.1 m;
- replace existing chlorination system with new equipment consisting of two chlorinators, two floor mounted injectors, chlorine gas analyzers and a two cylinder scale with alarm;
- existing diesel driven pump converted to a standby diesel generator with a capacity of 75 kW and two 1135 L fuel storage tanks;
- one sodium silicate metering pump with a maximum capacity of 0.063 L/s and two 200 L solution tanks;
- modifications to the wet well of the pumping station and architectural modifications to the building;
- station pipework, valves, meters, heating & ventilation, electrical and control systems and inlet pipe modifications all in accordance with Design Brief, dated December 1995, final plans and specifications prepared by Wardrop Engineering Inc., Consulting Engineers.

Water Treatment Plant Expansion (Phase 2)

- convert existing high lift pumping station to a low lift pumping station and replace the existing pumps with three (3) low lift pumps each rated at 25 L/s at a T.D.H. of 14.3 m;
- A new treatment plant building, adjacent to the existing pumping station, housing two (2) conventional treatment package units each rated at 25 L/s and consisting of two static mixers, flocculation, tube settler clarification and multi-media gravity filtration;
- six (6) metering pumps, two for liquid alum each rated at 510 mL/min; two for soda ash each rated at 870 mL/min and two for polymer each rated at 40 mL/min including a 22740 L alum storage tank and three (3) 1090 L day tanks;
- air scour blower, for filter backwash, rated at 260 L/s @ 8.38 kPa;

McNEELY ENGINEERING CONSULTANTS LTD.
880 Taylor Creek Dr., Orléans, Ontario, K1C 1T1 Tel: (613) 830-7500
880 Promenade Taylor Creek, Orléans, Ontario, K1C 1T1 Tél: (613) 830-7500

FAX : (613) 830-7506

DATE: 09-Dec-96 **FILE/DOSSIER:** M-4650-004

No. PAGES (INCL. COVER/COUVERTURE): 1

TO / A:	Sandra Latorre	**OF / DE:**	XCG	**FAX No.:**	1-905-891-2554
CC:	Elise Campbell	**OF / DE:**	Twp of North Plantagenet	**FAX No.:**	1-613-673-4812
CC:		**OF / DE:**		**FAX No.:**	

REFERENCE / OBJET: Wendover Water Treatment Plant

MESSAGE

Mrs. Latorre:

We have reviewed your letter dated December 5 , 1996 pertaining to the upgrade of the Wendover Water Supply Detail design for the water treatment plant is only in the initial stages, however, we can provide the following information.

The treatment system will be based on conventional processes consisting of coagulation, sedimentation and filtration. Chemical addition will consist of alum and a polymer for coagulation, sodium hydroxide for pH/alkalinity control and sodium hypochlorite for post disinfection. Serious consideration is being given to limit the formation of disinfection by-products. As such sodium hypochlorite will not be used on a continuous basis on the raw water stream (Ottawa River). We note that the disinfection process continues to merit further consideration as detail design progresses.

Please call if you have any questions.

from / de : Alain C. Gonthier, P.Eng.

ORIGINAL TO FOLLOW / COPIE A SUIVRE: No
RESPONSE REQUIRED / RÉPONSE REQUISE: No

APPENDIX D
COST ESTIMATES

TABLE 5.1: COST ESTIMATE FOR UPGRADE OF WATER TREATMENT FACILITIES: THM STUDY POPULATION BASED FLOW *

Community	Population	Flow (a)	Treatment Strategy	O&M Costs	Capital Cost Ammortized in 20 yr. @ 7%	Annual Cost (b)			Capital Cost
		ML/d		$/m³	$/m³	Capital	O&M	Total	$
Madsen	300	0.18	Pretreatment +						
			Nanofiltration +						
			Chlorine Disinfection						
			Total	1.35	0.48	31,433	88,695	120,128	333,000
			Microfiltration +						
			Chlorine Disinfection + Ammoniation						
			Total	0.45	0.68	38,229	29,565		406,000
			Full Conventional Treatment	1.68	0.69	38,701	103,806	142,507	410,000
McFarlane Lake	300	0.18	Chlorine Disinfection + Ammoniation	0.20	0.11	7,363	13,140	20,503	78,000
			Microfiltration +						
			Chlorine Disinfection + Ammoniation						
			Total	0.45	0.58	38,229	29,565	67,794	405,000
			Slow Sand Filtration +	0.50					925,000
			Chlorine Disinfection + Ammoniation	0.20					75,000
			Total	0.70	1.44	94,393	45,990	140,383	1,000,000
			Direct Filtration	0.61	0.18	11,516	33,507	45,023	122,000
Vermillion Bay	500	0.30	Chlorine Dioxide Disinfection	0.30	0.09	10,383	32,850	43,233	110,000
			Chlorine Disinfection + Ammoniation	0.17	0.07	8,023	19,053	27,076	85,000
			Microfiltration +						
			Chlorine Disinfection + Ammoniation						
				0.32	0.38	42,005	35,040	77,045	446,000
			Direct Filtration	0.40	0.16	17,085	43,800	60,885	181,000
Wendover	850	0.51	Microfiltration +						
			Nanofiltration +						
			Chlorine Disinfection						
			Total	0.66	0.33	60,883	122,859	183,742	645,000
			Microfiltration +						
			Chlorine Disinfection + Ammoniation						
			Total	0.26	0.26	49,084	48,399	97,483	620,000
			Full Conventional Treatment	0.68	0.35	64,942	126,582	191,524	688,000

TABLE 5.1: COST ESTIMATE FOR UPGRADE OF WATER TREATMENT FACILITIES: THM STUDY POPULATION BASED FLOW *

Community	Population	Flow (a) ML/d	Treatment Strategy	O&M Costs $/m^3$	Capital Cost Ammortized in 20 yr. @ 7% $/m^3$	Annual Cost (b) Capital	Annual Cost (b) O&M	Annual Cost (b) Total	Capital Cost $
Hudson	500	0.30	Microfiltration + Nanofiltration + Chlorine Disinfection						
			Total	0.93	0.47	50,972	101,835	152,807	540,000
			Slow Sand Filtration +	0.30					1,500,000
			Chlorine Disinfection + Ammoniation	0.17					85,000
			Total	0.47	1.37	149,613	51,465	201,078	1,586,000
			Full Conventional Treatment	1.16	0.47	51,727	125,925	177,652	548,000
Sioux Lookout	5,000	3.00	Microfiltration + Nanofiltration + Chlorine Disinfection						
			Total	0.48	0.21	228,431	525,600	754,031	2,420,000
			Microfiltration + Chlorine Disinfection + Ammoniation						
			Total	0.18	0.12	128,374	197,100	325,474	1,360,000
			Full Conventional Treatment	0.11	0.11	118,935	120,450	239,385	1,260,000
Red Lake	2,100	1.26	Pretreatment + Nanofiltration + Chlorine Disinfection						
			Total	0.62	0.16	74,004	239,148	313,152	784,000
			Microfiltration + Chlorine Disinfection + Ammoniation						
			Total	0.18	0.16	72,683	82,782	155,465	770,000
			Full Conventional Treatment	0.23	0.18	84,954	105,777	190,731	900,000
Cochenour	550	0.33	Microfiltration + Nanofiltration + Chlorine Disinfection						
			Total	0.9	0.44	52,860	108,405	161,265	660,000
			Microfiltration + Chlorine Disinfection + Ammoniation						
			Total	0.36	0.36	42,949	42,158	85,106	456,000
			Full Conventional Treatment	1.70	0.43	51,727	204,765	256,492	548,000

TABLE 5.2: COST ESTIMATE FOR UPGRADE OF WATER TREATMENT FACILITIES: THM STUDY BASED ON QUESTIONNAIRE FLOW *

Community	Population	Flow ML/d	Treatment Strategy	O&M Costs $/m³	Capital Cost Ammortized in 20 yr. @ 7% $/m³	Annual Cost (b)			Capital Cost $
						Capital	O&M	Total	
Hudson	500	0.083	Microfiltration + Nanofiltration + Chlorine Disinfection						
			Total	1.52	0.93	28,318	46,198	74,516	300,000
			Slow Sand Filtration + Chlorine Disinfection + Ammoniation						
			Total	0.50	1.46	44,365	15,197	59,561	470,000
			Full Conventional Treatment	3.14	0.78	23,598	95,436	119,034	250,000
Sioux Lookout	5,000	7.87	Microfiltration + Nanofiltration + Chlorine Disinfection						
			Total	0.41	0.19	547,479	1,178,165	1,725,643	5,800,000
			Microfiltration + Chlorine Disinfection + Ammoniation						
			Total	0.18	0.12	358,693	517,243	875,936	3,800,000
			Full Conventional Treatment	0.10	0.11	311,497	287,357	598,854	3,300,000
Red Lake	2,060	3.11	Pretreatment + Nanofiltration + Chlorine Disinfection						
			Total	0.44	0.12	141,589	495,128	636,717	1,500,000
			Microfiltration + Chlorine Disinfection + Ammoniation						
			Total	0.18	0.13	151,029	204,410	355,439	1,600,000
			Full Conventional Treatment	0.11	0.11	122,711	124,917	247,628	1,300,000
Cochenour	700	1.19	Microfiltration + Nanofiltration + Chlorine Disinfection						
			Total	0.44	0.27	115,631	191,652	307,284	1,225,000
			Microfiltration + Chlorine Disinfection + Ammoniation						
			Total	0.17	0.21	89,673	73,746	163,419	950,000
			Full Conventional Treatment	0.27	0.19	82,594	117,126	199,719	876,000

TABLE 5.1: COST ESTIMATE FOR UPGRADE OF WATER TREATMENT FACILITIES: THM STUDY POPULATION BASED FLOW *

Community	Population	Flow (a)	Treatment Strategy	O&M Costs	Capital Cost Ammortized in 20 yr. @ 7%	Annual Cost (b)			Capital Cost
		ML/d		$/m³	$/m³	Capital	O&M	Total	$
Balmertown	1,600	0.96	Pretreatment + Nanofiltration + Chlorine Disinfection Total	0.32	0.18	62,299	112,128	174,427	660,000
			Microfiltration + Chlorine Disinfection + Ammoniation Total	0.19	0.18	63,243	66,576	129,819	670,000
			Full Conventional Treatment	0.33	0.23	78,912	115,632	194,544	836,000
Port Carling	800	0.48	Pretreatment + Nanofiltration + Chlorine Disinfection Total	0.85	0.25	43,421	148,920	192,341	460,000
			Microfiltration + Chlorine Disinfection + Ammoniation	0.25	0.27	48,140	43,800	91,940	610,000
			Chlorine Disinfection + Ammoniation	0.14	0.05	8,967	24,528	33,495	95,000
			Chlorine Dioxide Disinfection	0.17	0.09	15,103	29,784	44,887	160,000
			Direct Filtration	0.24	0.14	24,070	42,048	66,118	255,000
Thunder Bay (Loch Lomond) [c]	45,000	22.70	Chlorine Dioxide Disinfection	0.04	0.04	330,375	331,420	661,795	3,600,000
			Chlorine Disinfection + Ammoniation	0.03	0.01	122,711	248,565	371,276	1,300,000
			Microfiltration + Chlorine Disinfection + Ammoniation	0.10	0.09	759,863	828,550	1,588,413	8,050,000
			Direct Filtration	0.06	0.12	1,000,565	497,130	1,497,695	10,600,000
Thunder Bay (Bare Point) [c]	45,000	22.70	Microfiltration + Chlorine Disinfection	0.09	0.09	757,031	745,695	1,502,726	8,020,000
			Direct Filtration	0.06	0.12	1,000,565	497,130	1,497,695	10,600,000

* Differences in Annual Costs may be noted for systems with similar flows; this reflects the fact that consideration of local factors has been taken into account

Assumptions:

(a) estimate based on existing population, consumption of 400L/person/day; additonal 50% for fire
(b) all cost in 1997 Canadian dolars, US$ to CND$ conversion of 1.4; capital cost amortized over 20 years at 7%
(c) It should be noted that the two supply alternatives for Thunder Bay - Loch Lomond and expansion of Bare Point WTP will require different additional capital costing issues; for the expansion of the Bare Point option, supply balancing, a trunk main and booster pumping is needed in addition to pumping at the plant; for the Loch Lomond alternative no pumping is required

- **Other:** This estimate is only preliminary. Potential savings may be realised following site examination especially in the use of existing equipment/facilities.

XCG Consultants Ltd.
02/23/98

TABLE 5.2: COST ESTIMATE FOR UPGRADE OF WATER TREATMENT FACILITIES: THM STUDY BASED ON QUESTIONNAIRE FLOW *

Community	Population	Flow	Treatment Strategy	O&M Costs	Capital Cost Ammortized in 20 yr. @7%	Annual Cost (b)			Capital Cost
		ML/d		$/m³	$/m³	Capital	O&M	Total	$
Balmertown	1,570	6.51	Pretreatment + Nanofiltration + Chlorine Disinfection Total	0.43	0.12	283,179	1,009,895	1,293,074	3,000,000
			Microfiltration + Chlorine Disinfection + Ammoniation Total	0.18	0.13	302,057	427,720	729,778	3,200,000
			Full Conventional Treatment	0.11	0.10	235,982	261,385	497,367	2,600,000
Port Carling	800	0.58	Pretreatment + Nanofiltration + Chlorine Disinfection Total	0.79	0.24	50,972	165,106	216,078	540,000
			Microfiltration + Chlorine Disinfection + Ammoniation Total	0.22	0.26	52,860	46,198	99,058	660,000
			Chlorine Disinfection + Ammoniation	0.13	0.04	9,062	27,299	36,361	96,000
			Chlorine Dioxide Disinfection	0.14	0.09	17,935	29,399	47,334	190,000
			Direct Filtration	0.21	0.14	29,262	44,098	73,360	310,000
Thunder Bay (Loch Lomond) (c)	45,000	26.50	Chlorine Dioxide Disinfection	0.04	0.03	330,375	386,827	717,202	3,600,000
			Chlorine Disinfection + Ammoniation	0.03	0.03	283,179	290,120	573,299	3,000,000
			Microfiltration + Chlorine Disinfection + Ammoniation Total	0.12	0.18	1,699,073	1,160,481	2,859,554	18,000,000
			Direct Filtration	0.06	0.10	1,000,565	580,241	1,580,806	10,600,000
Thunder Bay (Bare Point) (c)	45,000	26.50	Microfiltration + Chlorine Disinfection Total	0.11	0.18	1,696,241	1,063,774	2,760,015	17,970,000
			Direct Filtration	0.06	0.10	1,000,565	580,241	1,580,806	10,600,000

- * Differences in Annual Costs may be noted for systems with similar flows; this reflects the fact that consideration of local factors has been taken into account

Assumptions:

(b) all cost in 1997 Canadian dolars, US$ to CND$ conversion of 1.4; capital cost amortized over 20 years at 7%

(c) it should be noted that the two supply alternatives for Thunder Bay - Loch Lomond and expansion of Bare Point WTP will require different additional capital costing issues; for the expansion of the Bare Point option, supply balancing, a trunk main and booster pumping is needed in addition to pumping at the plant; for the Loch Lomond alternative no pumping is required

Other: This estimate is only preliminary. Potential savings may be realised following site examination especially in the use of existing equipment/facilities.

TABLE 5.2: COST ESTIMATE FOR UPGRADE OF WATER TREATMENT FACILITIES: THM STUDY BASED ON QUESTIONNAIRE FLOW *

Community	Population	Flow	Treatment Strategy	O&M Costs	Capital Cost Ammortized In 20 yr. @ 7%	Annual Cost (b)			Capital Cost
		ML/d		$/m^3	$/m^3	Capital	O&M	Total	$
Madsen	300	0.17	Pretreatment + Nanofiltration + Chlorine Disinfection Total	1.35	0.49	30,206	83,890	114,096	320,000
			Microfiltration + Chlorine Disinfection + Ammoniation Total	0.45	0.43	26,430	27,976	54,406	280,000
			Full Conventional Treatment	1.60	0.61	37,757	99,470	137,227	400,000
McFarlane Lake	240	0.21	Chlorine Disinfection + Ammoniation	0.19	0.10	7,551	14,831	22,382	80,000
			Microfiltration + Chlorine Disinfection + Ammoniation Total	0.40	0.36	28,318	31,222	59,540	300,000
			Slow Sand Filtration + Chlorine Disinfection + Ammoniation Total	0.43	0.63	49,084	33,564	82,648	520,000
			Direct Filtration	0.48	0.17	13,215	37,467	50,682	140,000
Vermillion Bay	550	0.48	Chlorine Dioxide Disinfection	0.17	0.09	15,103	29,827	44,930	160,000
			Chlorine Disinfection + Ammoniation	0.14	0.05	9,439	24,564	34,003	100,000
			Microfiltration + Chlorine Disinfection + Ammoniation Total	0.22	0.26	44,365	38,600	82,964	470,000
			Direct Filtration	0.24	0.14	25,014	42,109	67,123	265,000
Wendover	850	0.62	Microfiltration + Nanofiltration + Chlorine Disinfection Total	0.67	0.33	75,042	128,125	203,168	795,000
			Microfiltration + Chlorine Disinfection + Ammoniation Total	0.26	0.22	50,028	58,908	108,936	630,000
			Full Conventional Treatment	0.50	0.31	70,795	113,285	184,080	760,000